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Section 2 of 4

Document Information			
Document #	DOE/RL-2004-66	Revision	DFT A
Title	FOCUSED FEASIBILITY STUDY FOR THE BC CRIBS & TRENCHES AREA WASTE SITES		
Date	05/24/2005		
Originator		Originator Co.	DOE-RL
Recipient		Recipient Co.	
References			
Keywords			
Projects			
Other Information			

APPENDIX C

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

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FIGURES

TABLES

TERMS

95UCL	95th upper confidence level
ALE	Fitzner-Eberhardt Arid Lands Ecology Reserve
BCG	biota concentration guide (see DOE-STD-1153-2002)
BDAC	Biota Dose Assessment Committee
bgs	below ground surface
BRMaP	*Hanford Site Biological Resources Management Plan* (DOE/RL-96-32)
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (also known as *Superfund*)
CFR	*Code of Federal Regulations*
CLARC	cleanup levels and risk calculations (see Ecology 94-145)
COC	contaminant of concern
CONV	conventional parameter
COPC	contaminant of potential concern
C_s	soil concentration
CSM	conceptual site model
CUL	cleanup level
C_w	groundwater concentration
CZ	contaminated zone
DOE	U.S. Department of Energy
ECAP	Ecological Compliance Assessment Project
Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FS	feasibility study
GWP	groundwater protection
HHRA	human health risk assessment
HQ	hazard quotient
IRIS	Integrated Risk Information System
K_d	distribution coefficient
K_ds	chemical-specific distribution coefficient
Max Detect	maximum detection
MCL	maximum contaminant level
NA	not available
NOAEL	no observed adverse effect level
OSWER	Office of Solid Waste Emergency Response
OU	operable unit
PCB	polychlorinated biphenyl
PEF	particulate emissions factor
PPRTV	Provisional Peer-Reviewed Toxicity Values
RA	risk assessment
RAD	radiological

RAGS	Risk Assessment Guidance for Superfund
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation (Plant or process)
RESRAD	RESidual RADioactivity (dose model)
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RLS	radionuclide logging system
RME	reasonable maximum exposure
SAC	System Assessment Capability
SLERA	screening-level ecological risk assessment
STOMP	Subsurface Transport Over Multiple Phases (code)
SVOC	semivolatile organic compound
SZ	shallow zone
TBP	tributyl phosphate
TIC	tentatively identified compound
TPH	total petroleum hydrocarbon
Tri-Parties	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology
TRU	transuranic (waste materials contaminated with more than 100 nCi/g of transuranic materials having half-lives longer than 20 years)
UCF	unit conversion factor
UCL	upper confidence limit
URP	Uranium Recovery Process
VF	volatilization factor
VOC	volatile organic compound
WAC	*Washington Administrative Code*
WDNR	Washington Department of Natural Resources
WIDS	Waste Information Data System

APPENDIX C

HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

C1.0 INTRODUCTION

This appendix provides the results of the baseline human health risk assessment (HHRA) (Section C3.0) and screening-level ecological risk assessment (SLERA) (Section C4.0) for three sites in the BC Cribs and Trenches Area: the 216-B-26 Trench, 216-B-46 Crib, and 216-B-58 Trench. Two of these sites are 200-TW-1 representative sites (see DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit))*. The other (216-B-58 Trench) was a representative site in the 200-LW-1 Operable Unit (OU); this site has since been transferred to the 200-TW-1 OU. Figure C-1 shows locations of the BC Cribs and Trenches Area waste sites. Figures C-2 through C-5 show details of the sites' contaminant distributions.

The HHRA and ecological risk assessments (ERA) described in this appendix address pathways associated with shallow zone soil (0 to 4.6 m [0 to 15 ft] below ground surface [bgs]) for estimating human health and ecological risks and deep zone soil (from the soil surface to the water table) for evaluating protection of the groundwater from vadose zone contaminants.

These risk assessments (RA) were performed to determine whether a potential for risk to human health and the environment exists under current and reasonably anticipated future site-use conditions. The results are used, in part, to determine whether remedial action may need further evaluation and to focus the feasibility study (FS).

C1.1 ORGANIZATION OF THE RISK ASSESSMENT

This RA consists of the following components:

- **Conceptual site model (CSM):** Identifies the pathways by which human and ecological exposures could occur.
- **HHRA:** Provides the results of the contaminant of potential concern (COPC) selection process, human exposure assessment, toxicity assessment, and risk characterization.
- **SLERA:** Provides the results of the screening level ecological risk assessment.

C2.0 CONCEPTUAL SITE MODEL

The CSM identifies the means by which human or ecological receptors on or near the BC Cribs and Trenches Area waste sites could come into contact with chemicals in environmental media. The CSM addresses exposures that could result under current site conditions and from reasonably anticipated potential future uses for the site and the surrounding areas.

This CSM provides a current understanding of the sources of contamination, physical setting, and current and future land use, and identifies potentially complete human and ecological exposure pathways for the study area. Information generated during the remedial investigation (RI)/FS process has been incorporated into this CSM to identify potential exposure scenarios.

C2.1 ECOLOGICAL SETTING

Information about the ecological setting is presented in more detail in DOE/RL-2001-54, *Central Plateau Ecological Evaluation Report*. The environmental setting encompasses the terrestrial habitats within the area of the waste sites. The availability and quality of terrestrial habitats determine the wildlife types that can be present and the likelihood that wildlife use the areas associated with the waste sites in the study area.

C2.1.1 Terrestrial Habitats and Vegetation at the BC Cribs and Trenches Area Waste Sites

Environmental monitoring has been an ongoing activity since the early days of the Hanford Site. The monitoring efforts continue today, and a significant body of information exists about the ecology of the Central Plateau. The latest data collection efforts focused on the Central Plateau and the 200 Areas were conducted in 2000 and 2001. The information collected was compiled into DOE/RL-2001-54.

The Hanford Site is located within the Columbia Basin ecoregion, a nearly 6-million-hectare (14.8-million-acre) region once dominated by steppe and shrub-steppe vegetation (Franklin and Dyrness 1973, *Natural Vegetation of Oregon and Washington*). Today, an estimated 60 percent of the shrub-steppe habitat in Washington State has been converted to other uses by humans, as reported in TNC (1999), *Biodiversity Inventory and Analysis of the Hanford Site, Final Report 1994-1999*.

The habitats associated with the Central Plateau have been characterized, mapped, and described in recent years by WHC-SD-EN-TI-216, *Vegetation Communities Associated with the 100-Area and 200-Area Facilities on the Hanford Site*; TNC (1999); and documents produced by the Pacific Northwest National Laboratory (e.g., PNL-8942, *Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern*; PNNL-13230, *Hanford Site Environmental Report for Calendar Year 1999*).

Institutional controls and limited access to the Hanford Site for nearly 60 years have preserved the shrub-steppe ecosystems in some areas, while other locations (e.g., at facilities and waste sites) are highly disturbed. The Hanford Site as a whole and the U.S. Department of Defense Yakima Training Center are considered significant parcels within the Columbia Basin ecoregion, because they contain the largest remaining areas of relatively undisturbed shrub-steppe habitat (Smith 1994, *Evaluating the Conservation of Avian Diversity in Eastern Washington: A Geographic Analysis of Upland Breeding Birds*; TNC 1999).

The shrub-steppe community present on the Hanford Site is characterized by three or four layers of vegetation, depending on its stage of succession: (1) an overstory composed mostly of big sagebrush (sagebrush) (*Artemisia tridentata*), (2) a tall understory (bluebunch wheatgrass [*Agropyron spicatum*]), (3) a short understory, often dominated by Sandberg's bluegrass (*Poa sandbergii*), and (4) the cryptogamic crust (i.e., algae, lichens, and mosses on the soil surface). On the Central Plateau outside of the perimeter fence lines of the industrialized 200 Areas, the native shrub-steppe habitat dominates except in areas that have been disturbed by waste disposal operations (e.g., large cooling-water disposal ponds) or by range fires. Big sagebrush does not resprout after fire (Young and Evans 1977, "Arrowleaf Balsamroot and Mules Ear Seed Germination"). Sagebrush must grow from seed and may take up to 15 years to return after a fire. Grasses, however, are more fire tolerant, and cheatgrass (*Bromus tectorum*) can assume dominance after a fire (West and Hassan 1985, "Recovery of Sagebrush-Grass Vegetation Following Wildlife"). Russian thistle (*Salsola kali*) an early successional annual species and dominates recently disturbed soils. Disturbed areas associated with waste sites and range fires offer lower quality habitat and have low-community diversity, whereas relatively undisturbed sagebrush-grassland shrub-steppe habitat supports a higher number of organisms (i.e., has the highest biodiversity).

Within the industrial area fence lines, approximately 19 percent of the area is shrub-steppe and is relatively undisturbed; however, most of this land has been designated for future operations, such as expansion of the Central Waste Complex and operation of the Immobilized Low-Activity Waste Disposal Facility. The disturbed industrial land within the fence lines is predominantly gravel, buildings, and roads, with little vegetation. The disturbed habitat supports a very limited number of organisms (i.e., has low biodiversity). Sensitive species rarely are present in the disturbed habitat associated with waste management.

In the native shrub-steppe habitat surrounding the 200 Areas, the most prevalent shrub is big sagebrush, and the understory is dominated by the native perennial Sandberg's bluegrass and cheatgrass. Other shrubs present in the Central Plateau include rabbitbrush (*Chrysothamnus* spp.), spiny hopsage (*Grayia spinosa*), and antelope bitterbrush (*Purshia tridentata*).

Large areas of disturbed ground dominated by annual grasses and herbaceous plants are present in the 200 Areas. Vegetation/habitat maps for the Central Plateau are provided in Appendix B of DOE/RL-2001-54. Disturbed and nonvegetated (gravel or asphalt) areas in the Central Plateau have minimal vegetative cover (<10 percent) (WHC-SD-EN-TI-216) and are primarily the result of either mechanical disturbance (e.g., from road clearing or facility construction) or range fires. The waste sites in the BC Cribs and Trenches Area have been highly disturbed and are either nonvegetated, graveled surfaces, or planted with wheatgrass.

In less disturbed parcels of shrub-steppe on the Hanford Site, the ground surface is covered with a fragile thin crust (cryptogamic crust), consisting of mosses, lichen, algae, and bacteria that protect the soil beneath. The cryptogamic crust prevents erosion, retains moisture, and provides nutrients within the surface soils. The cryptogamic crust is an integral component of the arid terrestrial ecosystem, and its disturbance compromises the succession of native species. In the absence of the cryptogamic crust, disturbed soils are vulnerable to invasion by non-native and weedy colonizing species. The principal colonizers of disturbed sites are non-native annual species, such as Russian thistle (*Salsola kali*), Jim Hill mustard (*Sisymbrium altissimum*), and cheatgrass.

Mechanical disturbance typically results in the loss of soil structure and disruption of nutrient cycling, which have a significant effect on the plant species that recolonize a site. Many waste sites have been backfilled with clean soil and planted with crested (*Agropyron cristatum*) or Siberian wheatgrass (*Agropyron sibericum*) to stabilize the surface soil, control soil moisture, or displace more invasive deep-rooted species such as Russian thistle (PNNL-6415, *Hanford Site National Environmental Policy Act [NEPA] Characterization*). Many interim-stabilized waste sites are treated with herbicide as needed to prevent the uptake of underground contamination by deep-rooted plants. These sites have varying levels of disturbance. Some waste sites are highly disturbed, consisting of a gravel surface; others have a light vegetative cover of grasses and herbaceous plants; and yet others exhibit varying degrees of succession supporting the growth of shrubs. The most common organisms inhabiting the waste site areas are ants, beetles, and mice. Ants tunnel underground and move soil to the surface. The ability of ants to move contaminants to the surface at the Hanford Site is not well documented. Biota samples in conjunction with soil samples would be helpful in understanding the completeness of this exposure pathway.

C2.1.1.1 Terrestrial/Avian Wildlife

The number and species of wildlife endemic to the Central Plateau have been evaluated in a number of sources, including ecological characterization reports (e.g., PNL-2253, *Ecology of the 200 Area Plateau Waste Management Environs: A Status Report*; PNL-8942).

A recent Ecological Compliance Assessment Project (ECAP) survey of the Central Plateau evaluated the abundance and distribution of birds, small mammals (mice), reptiles, and invertebrate species. DOE/RL-2001-54, Table 2-3, summarizes the most common organisms observed or captured on the 200 Areas Central Plateau.

The largest mammal frequenting the Central Plateau is the mule deer (*Odocoileus hemionus*). While mule deer are much more common along the Columbia River, the few that forage throughout the Central Plateau make up a distinct group called the "central population" (PNNL-11472, *Hanford Site Environmental Report for Calendar Year 1996)*. A large elk herd (*Cervus canadensis*) currently resides on the Fitzner-Eberhardt Arid Lands Ecology Reserve (ALE). Occasionally a few elk have been observed south of the 200 Areas. However, the herd on the ALE recently was thinned; therefore, the elk are not expected to continue expanding their range into the Central Plateau.

Other mammals common to the Central Plateau are badgers (*Taxidea taxus*), coyotes (*Canis latrans*), Great Basin pocket mice (*Perognathus parvus*), northern pocket gophers (*Thomomys* *talpoides*), and deer mice (*Peromyscus maniculatus*). Jackrabbits (*Lepus californicus*) also are present in low numbers in the 200 Areas. Badgers are known for their digging ability and have been suspected of excavating contaminated soil at Central Plateau radioactive waste sites (BNWL-1794, *Distribution of Radioactive Jackrabbit Pellets in the Vicinity of the B-C Cribs, 200 East Area, USACE Hanford Reservation*). The majority of badger diggings are a result of searches for food, especially for other burrowing mammals such as pocket gophers and mice. Coyotes also are a top mammalian predator on the Hanford Site. They are opportunistic feeders and consume a variety of prey including mice, rabbits, birds, snakes, lizards, and insects, in addition to scavenging on carrion along roadways and eating fruit from agricultural fields. They are the most widely ranging mammals within the Central Plateau, with home territories ranging from 800 to 8,000 ha (0.3 to 30 mi^2). Pocket gophers and mice (especially Great Basin pocket mice and deer mice) are abundant in the Central Plateau. They predominantly consume vegetation and can excavate large amounts of soil as they construct their burrows (Hakonson et al. 1982, "Disturbance of a Low-Level Waste Burial Site Cover by Pocket Gophers"). Mammals associated with buildings and facilities include Nuttall's cottontails (*Sylvilagus nuttallii*), house mice (*Mus musculus*), Norway rats (*Rattus norvegicus*), and various bat species.

Common bird species in the Central Plateau include western meadowlarks (*Sturnella neglecta*), horned larks (*Eremophila alpestris*), and western kingbirds (*Tyrannus verticalus*). Species associated with the industrialized portions of the Central Plateau include rock doves (*Columba livia*), starlings (*Sturnus vulgaris*), black-billed magpies (*Pica pica*), and ravens (*Corvus corax*). Burrowing owls (*Athene cunicularia*) commonly nest in abandoned badger or coyote holes, or in open-ended stormwater pipes along roadsides in more industrialized areas. Loggerhead shrikes (*Lanius ludovicianus*) and sage sparrows (*Amphispiza belli*) are common nesting species in habitats dominated by sagebrush. Long-billed curlews (*Numenius americanus*) have been observed nesting on inactive Central Plateau waste sites. Recent characterizations of the Central Plateau have identified western meadowlarks as being the most widely distributed bird species, followed by horned larks and mourning doves (*Zenaida macroura*). Other conspicuous birds include terrestrial game birds (e.g., California quail [*Callipepla californica*], chukar [*Alectoris chukar*], ring-necked pheasant [*Phasianus colchicus*]), passerine species, and raptors (e.g., red-tailed hawk [*Buteo jamaicensis*], northern harrier [*Circus cyaneus*]).

Reptiles found in the Central Plateau include gopher snakes (*Pituophis melanoleucus*) and side-blotched lizards (*Uta stansburiana*). Rattlesnakes (*Crotalus viridis*) also have been observed. Reptile sightings were not widespread, with only 23 observations of side-blotched lizards at 316 sites surveyed during a 2001 ECAP survey (DOE/RL-2001-54, Appendix B).

Three of the most common groups of insects found at the Hanford Site include darkling beetles, grasshoppers, and ants. Insect studies near waste management facilities have concentrated on these three major groups. PNL-2713, *Shrub-Inhabiting Insects of the 200 Area Plateau, Southcentral Washington,* characterized the insects, including spiders, associated with major shrubs of the Central Plateau. Sagebrush, rabbitbrush, and hopsage were the three shrubs included in the study. Three areas were selected for collecting shrub-inhabiting insects: (1) near the BC Cribs and Trenches Area, (2) near the former Reduction-Oxidation (REDOX) Plant pond area, and (3) in a controlled area located on the nearby ALE. The study found that the seasonal pattern for insect abundance on rabbitbrush was bimodal, peaking in May or June and again in

September and October. Darkling beetles are a dominant part of the insect community in the Central Plateau where they occur with very little seasonal restriction, but exhibit dramatic changes in abundance from year to year (PNL-2253). Grasshoppers are herbivorous insects common in the Central Plateau. Their abundance cycles from year to year, with increased population size from May to July annually.

C2.1.2 Sensitive Habitats

Sensitive habitats include those identified as rare, wetland, or riparian. Sensitive habitats present on the Central Plateau include basalt outcrops, riparian areas, former wetland areas associated with historic liquid waste disposal, and vernal pools. Wetlands are protected by the Federal government under the *Clean Water Act of 1977* (Section 404) and the state government (RCW 90.48, "Water Rights – Environment," "Water Pollution Control," and WAC 173-20, "Shoreline Management Act--Lakes Constituting Shorelines of the State"). None of the BC Cribs and Trenches Area waste sites are associated with these types of sensitive habitats.

C2.1.3 Sensitive Species and Species of Concern

Sensitive species include threatened and endangered species, which are protected by Federal and state laws. Washington State defines sensitive species as any wildlife species native to the State of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats (WAC 232-12-297, "Fish and Wildlife, Department of," "Permanent Regulations," "Endangered, Threatened, and Sensitive Wildlife Species Classification," defines the term "sensitive"). Species of concern are those that do not have a Federal designation but that may warrant additional protection, because they are rare or stressed. None of the following sensitive species or species of concern has been identified associated with the waste sites in these OUs.

C2.1.3.1 Threatened and Endangered Species

Threatened and endangered species are plants and animals that are few in number and are protected by Federal regulations (50 CFR 17, "Wildlife and Fisheries," "Endangered and Threatened Wildlife and Plants"). An "endangered" species is one that is in danger of extinction throughout all or a significant portion of its range. A "threatened" species is one that is likely to become endangered in the foreseeable future. The *Endangered Species Act of 1973* requires conservation of threatened and endangered species.

Two federally protected species have been observed at the Hanford Site, the Aleutian Canada goose (*Branta canadensis leucopareia*) and the bald eagle (*Haliaeetus leucocephalus*). Both depend on the river corridor and rarely are seen in the Central Plateau. As migratory birds, these species also are protected under the *Migratory Bird Treaty Act* (1918).

The following text table shows the Federally listed threatened, endangered, and candidate species and species of concern and the threatened and endangered species listed by Washington State as identified on the Hanford Site. DOE/EIS-0286, Rev. 2, *Hanford Site Solid (Radioactive and*

Hazardous) Waste Program Environmental Impact Statement, Richland, Washington, also provides listings of Washington State candidate animal and plant species in Tables 4.13 and 4.14.

Common Name	Scientific Name	Federal (50 CFR 17)[a]	State[f,g]
Plants			
Columbia milkvetch	*Astragalus columbianus*	SC[b]	T
dwarf evening primrose	Camissonia (= Oenothera) pygmaea		T
Hoover's desert parsley	Lomatium tuberosum	SC	T
Loeflingia	Loeflingia squarrosa var. squarrosa		T
persistent sepal yellowcress	Rorippa columbiae	SC	T
Umtanum desert (wild) buckwheat	Eriogonum codium	T[d]C[c]	E
White Bluffs bladderpod	Lesquerella tuplashensis	C	E
white eatonella	Eatonella nivea		T
Ute ladies'-tresses[i]	*Spiranthes diluvialis*	T[d]	
Fish			
bull trout[i]	*Salvelinus confluentus*	T	
spring-run Chinook	Oncorhynchus tshawytscha	E[e]	C
Upper Columbia steelhead	Oncorhynchus mykiss	E	C
Middle Columbia steelhead	*Oncorhynchus mykiss*	T	C
Birds			
American white pelican	Pelecanus erythrorhychos		E
bald eagle[h]	Haliaeetus leucocephalus	T	T
ferruginous hawk	Buteo regalis	SC	T
greater sage grouse	*Centrocercus urophasianus phaios*	C	T
olive-sided flycatcher	*Contopus cooperi*	SC	
sandhill crane	Grus canadensis		E
willow flycatcher	*Empidonax trailii*	SC	
yellow-billed cuckoo[i]	*Coccyzus americanus*	C	
Reptiles			
Northern sagebrush lizard	*Sceloporous graciosus*	SC	

[a] 50 CFR 17, "Wildlife and Fisheries," "Endangered and Threatened Wildlife and Plants," Title 50, *Code of Federal Regulations*, Part 17, as amended.
[b] SC = Federal species of concern, 50 CFR 17 or available on the Internet at: http://www.fws.gov .
[c] C = Federal candidate species, 50 CFR 17 or available on the Internet at: http://www.fws.gov .
[d] T = Federal threatened species, 50 CFR 17 or available on the Internet at: http://www.fws.gov .
[e] E = Federal endangered species, 50 CFR 17 or available on the Internet at: http://www.fws.gov .
[f] Available on the Internet at: www.dnr.wa.gov/nhp/refdesk/lists/plantsxco/benton.html
[g] Available on the Internet at: www.wdfw.wa.gov/ ; select Habitat, Priority Habits and Species, Priority Habits and Species List, Species of Concern List.
[h] Currently under review for change in status.
[i] Not believed to be present on the Hanford Site, but identified by the U.S. Fish and Wildlife Service, 2003.

C2.1.3.2 Rare Plants

Rare plant species refer to any vascular plant species listed by the Washington Natural Heritage Program (2003) as endangered, threatened, or sensitive in Washington State. Beyond threatened and endangered species, the Washington Department of Natural Resources (WDNR) Natural Heritage Program and the Washington Department of Fish and Wildlife have prioritized the conservation of additional species. Data are available on state and global rarity, endemic species, and the resource level of concern to which the species is assigned at the Hanford Site. The list of species of concern, as presented in DOE/RL-96-32 (*Hanford Site Biological Resources Management Plan*) (BRMaP), is lengthy. The Nature Conservancy survey discovered 112 populations of 28 rare plant taxa on the Hanford Site (TNC 1999). Although rare plants were found dispersed throughout the Site, the highest densities occurred on the east end of Umtanum Ridge, the basalt-derived sands near Gable Mountain, the White Bluffs, Rattlesnake Mountain, and Yakima Ridge.

C2.1.3.3 Mammalian Species of Concern

Pygmy rabbit (Brachylagus idahoensis). Pygmy rabbits dig simple burrows in soil. They generally are found within a 30 m (98-ft) radius of their burrows during winter and expand their home range in spring and summer. The pygmy rabbit depends primarily on dense stands of big sagebrush for food and cover. The Idaho pygmy rabbits' diet consists largely of sagebrush in the winter, with grasses (39 percent) and forbs (10 percent) added in spring and summer.

C2.1.3.4 New-to-Science Species

The Nature Conservancy conducted a biodiversity survey of plants, mammals, reptiles, and amphibians, birds, and insects at the Hanford Site between 1994 and 1999 (TNC 1999). This survey found 2 species and 1 variety of plants and 41 species and 2 subspecies of insects that had not been known to science. Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Lesquerella tuplashensis*) and a new variety, basalt milk vetch (*Astragalus conjunctus* var. *rickardii*), were identified as new plant species. The new plant and insect species are listed at http://www.pnl.gov/ecomon/species/species.html.

The U.S. Fish and Wildlife and Washington State have not yet determined the protective status of these new-to-science species (i.e., whether or not they are considered threatened or endangered). The BRMaP offers guidance for the protection of most of these species. Rare plants were found dispersed throughout the Site; however, the highest densities occurred on the east end of Umtanum Ridge, the basalt-derived sands near Gable Mountain, the White Bluffs, Rattlesnake Mountain, and Yakima Ridge. Each vernal pool cluster contained one or more rare plants. The new-to-science plants and their habitat requirements are described in the following paragraphs.

Umtanum desert buckwheat (*Eriogonum codium*). The only known population of Umtanum desert buckwheat consists of approximately 5,200 plants on Umtanum Ridge in Benton County at the western edge of the Hanford Site. Umtanum desert buckwheat is a long-lived (possibly more than 100 years), extremely slow-growing, woody perennial that forms low mats (Dunwiddie et al. 2001, "Demographic Studies of *Eriogonum codium* Reveal, Caplow & Beck (Polygonaceae) in Washington"; and TNC 1999, *Biodiversity Inventory and Analysis of the*

Hanford Site Final Report 1994-1999). This singular population is restricted to a narrow, scattered distribution within a 1.6 km (1-mi) portion of Umtanum Ridge (Dunwiddie et al. 2001) and is not located near any of the waste sites considered here. The species grows exclusively on exposed basalt flow material of the Lolo Flow of the Wanapum basalt formation. The soils are classified as lithosols and are composed of fine reddish to blackish basalt overlain with pumice. Researchers from The Nature Conservancy have observed western harvester ants (*Pogonomyrmex occidentalis*) gathering mature Umtanum desert buckwheat seeds.

White Bluffs bladderpod (*Lesquerella tuplashensis*). White Bluffs bladderpod is a short-lived perennial that grows on the upper edge of the White Bluffs of the Columbia River in Franklin County, not near any of the waste sites considered here. The single known population of the species varies considerably between years, but censuses of adult (flowering) plants suggest more than 50,000 plants may be present during some years (TNC 1999). The plant is found in a near-vertical exposure of cemented, highly alkaline calcium carbonate paleosol (a "caliche" soil). This hard calcium carbonate paleosol caps several hundred feet of alkaline, easily eroded lacustrine sediments of the Ringold Formation. The species occurs intermittently in a narrow band (usually less than 10 m [33 ft] wide) along an approximately 17 km (10.6-mi) stretch of the bluff.

Basalt milk vetch (*Astragalus conjunctus* var. *rickardii*). Basalt milk vetch typically is associated with bunchgrass areas within big sagebrush-steppe communities. It has been found on the top and north end of Rattlesnake Mountain at the Hanford Site (TNC 1999). The basalt milk vetch has not been identified near any 200 Areas waste sites. The other known population of basalt milk vetch in Benton County is a small population on the Chandler Butte portion of the Horse Heaven Hills. This represents a more northern extension of the plant's range than had been known previously.

New-to-science insect species also were identified. The Nature Conservancy identified 2 beetles (*coleoptera*), 9 flies (*diptera*), 5 leaf-hoppers (*homoptera*), 7 bees, ants, and wasps (*hymenoptera*), and 20 butterflies and moths (*lepidoptera*) on the Hanford Site (TNC 1999). The insects were dispersed throughout the Site, with the new species found in shrub-steppe, areas around the basalt talus, springs, and upland areas. Early results indicated that the insects found in disturbed areas were strikingly different from those found in areas with relatively intact shrub-steppe habitat. Both the type of insects found and the timing of insect activity varied between the two habitats. For example, more scorpions were noted in the shrub-steppe than in disturbed habitats. Also of note was the uniqueness of the insects surrounding West Lake. None of the new-to-science insects would be expected on or near the BC Cribs and Trenches Area waste sites.

Based on the information about the habitat and wildlife in the Central Plateau, three primary areas of consideration are important to the decision-making process.

- The shrub-steppe habitat at the Hanford Site is one of the largest parcels of shrub-steppe in a region where the availability of this habitat is declining. Protection of shrub-steppe habitat at the Hanford Site is critical for the health of the regional ecosystem. The shrub-steppe habitat on the Hanford Site also provides for the most diverse community of plants and animals in the arid upland environment, and diverse communities are better able to cope with environment stresses, such as contamination, than uniform communities.

- Individual species, whose populations are limited and are designated as sensitive species, must be protected.

- Most waste sites on the Central Plateau of the Hanford Site are disturbed habitats covered with gravel or grasses and other small plants. These sites have a very low biodiversity of floral and faunal species and offer poor quality habitat for animals. Additionally, succession of native species has been slow in these disturbed areas. Recovery of disturbed habitats to a mature shrub-steppe community is estimated to take more than 100 years if left alone.

Because of the disturbance of the waste sites, little to no habitat exists at the present. Many of the waste sites in these OUs are located below 4.6 m (15 ft) bgs and would pose little threat to ecological receptors in the area. One important characteristic of the BC Cribs and Trenches Area waste sites is the presence of salts in the waste streams that were discharged to the soil. Historically, these salts have attracted animals, resulting in the release of contaminants to the environment when these animals burrowed into the waste sites to access them.

C2.2 CHARACTERIZATION OF LAND USE

The land-use boundary around the 200 East and 200 West Areas has been designated as industrial (exclusive) in DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan – Environmental Impact Statement*. All waste sites are located within the Central Plateau Industrial/Exclusive Zone (Core Zone).

Land use within the Central Plateau Industrial/Exclusive Zone of the 200 Areas currently is considered industrial (exclusive) and is defined as "preserving U.S. Department of Energy (DOE) control of the continuing remediation activities and use of the existing compatible infrastructure required to support activities such as dangerous waste, radioactive waste, and mixed waste treatment, and storage and disposal facilities" (DOE/EIS-0222-F). The waste sites inside the Central Plateau Industrial/Exclusive Zone meet the -definition of an industrial property under WAC 173-340-200, "Model Toxics Control Act --Cleanup," "Definitions," and WAC 173-340-745, "Model Toxics Control Act – Cleanup," "Soil Cleanup Standards for Industrial Properties," by meeting the following criteria: the waste sites do not serve as current residential areas, they have no potential to serve as future residential areas, access to the industrial property by the general public is not allowed or access is highly limited and controlled to address safety or security considerations, and food is not grown or raised on the property.

Future land use at the Hanford Site is uncertain; however, the DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) (i.e., Tri-Parties) have agreed that an industrial scenario will be used to evaluate waste sites within the Central Plateau Industrial/Exclusive Zone. Other scenarios, such as a hypothetical Native American subsistence scenario and an intruder scenario, also have been run to provide additional information to decision makers. WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection," Method B three-phase model was used to estimate nonradionuclide soil concentrations that are protective of groundwater.

Groundwater Beneficial Use

Local groundwater is not a current source of drinking water in the Central Plateau Industrial/Exclusive Zone. In addition, groundwater beneath the Central Plateau Industrial/Exclusive Zone is not anticipated to become a future source of drinking water. Under current conditions, no complete human exposure pathways to groundwater are assumed at the waste sites. Risks associated with current contamination in the groundwater were not evaluated in this assessment. Contaminated groundwater in the 200 East Area is being and will continue to be addressed under the 200-BP-5 and 200-PO-1 OUs.

C2.3 CONCEPTUAL EXPOSURE MODEL FOR HUMAN HEALTH AND THE ENVIRONMENT

This section describes the potential exposure pathways from site contaminants, based on currently available site information. The conceptual exposure model is formulated according to guidance (EPA/540/R-99/005, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual ([Part E, Supplemental Guidance for Dermal Risk Assessment])*, with the use of professional judgment and information on contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups associated with the waste sites.

An exposure pathway can be described as the physical course that a COPC takes from the point of release to a receptor. Chemical intake or exposure route is the means by which a COPC enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism for chemical release and transport
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population.

In the absence of any one of these components, an exposure pathway is considered incomplete and, by definition, no risk or hazard exists. Figure C-6 presents the conceptual exposure model for the waste site.

C2.3.1 Contaminant Sources

The primary sources of contaminants at the three sites are described in Table C-1.

C2.3.2 Release Mechanisms and Environmental Transport Media

The primary release mechanisms transporting the COPCs from the source, via environmental media, to potential receptors include the following:

- Infiltration, percolation, and leaching of contaminants from waste sites to groundwater
- Direct contact with shallow zone soil containing COPCs (receptor contact with onsite shallow zone soil replaces release and transport)
- Generation of dust emanating from shallow zone soil to ambient air from wind or during maintenance or construction activities at the waste site
- Volatilization of chemicals emanating from shallow zone soil to ambient air at the waste site.

C2.3.3 Potentially Complete Human Exposure Pathways and Receptors

Based on the current understanding of land-use conditions at and near the waste sites, the most plausible exposure pathways considered for characterizing human health risks are described in the following paragraphs.

The industrial land-use scenario is the baseline for evaluation in this RA. To provide additional information to decision makers, a Native American exposure scenario is presented.

For the purposes of this RA, the point of compliance for shallow zone soils is defined as 0 to 4.6 m (0 to 15 ft) bgs and is evaluated using soil samples collected in this zone. This depth range is a reasonable estimate of the depth of soil that could be excavated and distributed to the surface as a result of development activities. The point of compliance for deep zone soils is defined as those samples collected throughout the soil profile (i.e., from the surface to the water table) and used to evaluate the protection of groundwater pathways.

Evaluation of the radiological constituents in shallow zone soil (for the direct-contact exposure pathways) was conducted using two different methods. The first evaluation method is considered representative of current waste site conditions, because it accounts for a depth of clean cover over the waste site. The shielding effects of the clean cover influence the resulting dose and risk estimates. The second evaluation method is considered representative of worst-case conditions; it assumes that no clean cover is present over the top of the representative site (i.e., the exposure point concentration [EPC] is representative of the entire shallow zone).

C2.3.3.1 Industrial Land-Use Scenario

Under current and future waste site conditions, onsite industrial workers potentially could be exposed to shallow zone soils from the waste site. The industrial land-use scenario assumes that no groundwater from the waste site will be used for drinking purposes. Standard

WAC 173-340-745, Method C soil CULs for nonradiological constituents consider exposure through the direct-contact pathway (incidental soil ingestion and dermal contact) and inhalation of dust and vapors in ambient air. For radiological constituents, potential routes of exposure to shallow zone soil include external gamma radiation, incidental soil ingestion, and inhalation of dust particulates (Section C3.3.1 discusses the RESidual RADioactivity [RESRAD] model).

C2.3.3.2 Hypothetical Native American Subsistence Scenario

The DOE remains committed to considering Tribal exposure scenarios for conducting the RAs necessary to evaluate whether Hanford Site cleanup alternatives are protective of human health and the environment (Roberson 2002, "Hazard Categorization of EM Inactive Waste Sites as Less Than Hazard Category 3"). The Tri-Parties have interacted with the stakeholder Tribes over the past several years to obtain their input on developing a Native American exposure scenario or scenarios, including key parameters for the Central Plateau RA models.

The Tribes were involved in the RA framework workshops during the summer of 2002, and in October 2002, they were asked to provide written suggestions on specific RA parameters (exposure assumptions) for Tribal-use scenarios (DOE-RCA-2002-0584, 2002a, Letter [no title; topic: Tribal Input on the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) Risk Assessment], to Richard Gay, Confederated Tribes of the Umatilla Indian Reservation, from the Tri-Party Agreement signatories; DOE-RCA-2002-0584, 2002b, Letter [no title; topic: Tribal Input on CERCLA Risk Assessment], to Russell Jim, Confederated Tribes and Bands of the Yakama Nation, from the Tri-Party Agreement signatories; DOE-RCA-2002-0584, 2002c, Letter [no title; topic: Tribal Input on CERCLA Risk Assessment], to Patrick Sobotta, Nez Perce Tribe, from the Tri-Party Agreement signatories). This request culminated in a workshop in December 2002 that included the Tri-Parties and representatives from the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Nation, and the Nez Perce Tribe. The Yakamas and the Nez Perce participated in the workshop but believed they needed additional time to provide input. The Umatillas asked that the information from DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*, and Harris and Harper 1997, "A Native American Exposure Scenario," be used to calculate risk estimates for a Native American subsistence scenario. The information from this study was used to estimate potential risks to a Native American from radiological constituents.

The Native American subsistence scenario proposed in Harris and Harper (1997) represents a "typical" Native American culture that incorporates the use of the entire Columbia Basin for food, water, and shelter. This hypothetical scenario was evaluated to provide a basis of comparison (assuming unrestricted land use) to the site-specific scenario (i.e., industrial) previously described. Considerable uncertainty is associated with applying the Native American subsistence exposure assumptions to each waste site, and applying these assumptions likely overestimates the dose and risk associated with each waste site. Less uncertainty would be associated with risk estimates predicted on an area-wide basis, such as through the System Assessment Capability (SAC) process.[1]

C2.3.3.3 Protection of Groundwater

Constituents currently present throughout the soil column potentially could leach into groundwater beneath the waste site. Soil concentrations of nonradiological constituents protective of groundwater CULs were calculated for the unrestricted land-use scenario. For radiological constituents, future impacts to the groundwater ingestion pathway were evaluated.

C2.3.4 Potentially Complete Ecological Exposure Pathways and Receptors

Based on the current understanding of land-use conditions (industrial land use) at these waste sites and the surrounding habitat, the following ecological exposures potentially associated with the study area waste sites will be considered for characterizing ecological risks:

- Direct contact with, or ingestion of, surface soil by avian (e.g., western meadowlark) and terrestrial (e.g., coyote) wildlife that might use the waste sites
- Bioaccumulation through ingestion of food items (e.g., plants or prey) consumed by wildlife that might forage at the waste sites.

C2.3.5 Computation of Exposure Point Concentrations

The EPCs are estimated chemical concentrations that a receptor could come in contact with and are specific to each exposure medium (i.e., shallow and deep zone soils). For the direct-contact routes of exposure, EPCs are represented by concentrations directly measured in soil. For the inhalation route, modeling was performed to estimate constituent concentrations in air from particulate or vapor emissions from soil.

C2.3.5.1 Direct-Contact Exposure Point Concentrations

The EPCs were calculated using the best statistical estimate of an upper bound on the average exposure concentrations, in accordance with WAC 173-340-745(8), "Soil Cleanup Standards for Industrial Properties," "Compliance Monitoring." As stated in EPA PB-96-3373, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, the 95 percent upper confidence limit (UCL) on the mean is considered a conservative upper bound estimate that is not likely to underestimate the mean concentration, and most likely overestimates that concentration. The maximum detected concentration was used in place of the 95 percent UCL when the calculated 95 percent UCL was greater than the maximum detected value.

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[1]The hypothetical Native American subsistence scenario likely will be an iterative process and will become refined in the future through the RI/FS and Site cleanup processes.

C2.3.5.2 Ambient Air Exposure Point Concentrations

Air concentrations were estimated by modeling particulate or vapor emissions from the soil. Air concentrations from vapor emissions were estimated using a volatilization factor for those constituents that are considered volatile. Volatile constituents considered for the inhalation pathway are operationally defined as those constituents with a Henry's Law constant greater than 10^{-5} atm-m^3/mole and a molecular weight less than 200 g/mole (EPA 2002, *Region 9 [Preliminary Remediation Goals] PRGs 2002 Tables*. Air concentrations from fugitive dust emissions were estimated using a particulate emissions factor for those constituents that are not volatile. The following equation was used to estimate air concentrations from volatile or particulate emissions:

$$Air\ Concentration\left(\frac{mg}{m^3}\right) = C_s \times \left(\frac{1}{PEF}\ or\ \frac{1}{VF}\right)$$

where

C_s = soil concentration (mg/kg)
VF = volatilization factor (chemical-specific) (m^3/kg)
PEF = particulate emissions factor (1.32 x 10^9 m^3/kg).

The volatilization factors for volatile organic compounds identified as COPCs in shallow zone soil[1] and the particulate emissions factor used to estimate fugitive dust emissions were obtained from EPA/540/R-96/018, *Soil Screening Guidance: Users Guide.*

C3.0 HUMAN HEALTH RISK ASSESSMENT

This section presents HHRA information for the three sampled waste sites. Additionally, risks associated with the 216-B-46 Crib site are discussed in DOE/RL-92-70, *Phase I Remedial Investigation Report for 200-BP-1 Operable Unit.* Summary information presented in this RA includes the following:

- **HHRA guidance:** Lists the guidance documents used for the HHRA.
- **Selection of COPCs:** Identifies the constituents considered to be most important to the evaluation of human health risk.
- **Human exposure and toxicity assessment:** Identifies the pathways by which potential human exposures could occur; describes how exposures are evaluated; evaluates the magnitude, frequency, and duration of these exposures; and identifies the sources of toxicity values used.

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[1]Shallow zone soils are defined as those collected from zero to 4.6 m (15 ft) bgs.

- **Risk Characterization:** Integrates information from the exposure and toxicity assessments to characterize the risks to human health from potential exposure to contaminants in environmental media.
- **Identification of major uncertainties and assumptions:** Summarizes the basic assumptions used in the RA, as well as limitations of data and methodology.

C3.1 HUMAN HEALTH GUIDANCE

The procedures used for the HHRA are consistent with those described in WAC-173-340, "Model Toxics Control Act -- Cleanup," and the following DOE and EPA guidance documents:

- EPA/540/1-89/002, *Risk Assessment Guidance for Superfund (RAGS), Volume I -- Human Health Evaluation Manual, (Part A) Interim Final*
- EPA 1991, Office of Solid Waste Emergency Response (OSWER) Directive 9285.6-03, *Risk Assessment Guidance for Superfund, Vol. I, Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors, (Interim Final)*
- EPA/600/P-95/002Fa, *Exposure Factors Handbook*
- EPA/600/P-92/003C, *Proposed Guidelines for Carcinogen Risk Assessment*
- EPA/540/R-99/005
- EPA PB-96-3373.

C3.2 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN

The COPCs are those contaminants that should be carried through the human health risk quantification process. This component of the HHRA process summarizes those contaminants detected in environmental media and identifies the COPCs for environmental media that are accessible for human exposure. During the course of the HHRA, the COPCs are evaluated to identify and prioritize those contaminants that are estimated to pose an unacceptable risk and should be addressed by the FS.

C3.2.1 Data Used for Contaminant of Potential Concern Selection

Data evaluated for the sites in this RA include shallow and deep zone soil samples collected during the 200-TW-1 and 200-BP-1 RI investigations (DOE/RL-2002-42 and DOE/RL-92-70). Table C-2 summarizes all the samples included in this RA by station identification, sample identification, depth interval, and date of collection. The following rules were used to identify the data to be used in the RA.

- Estimated values flagged with a "B" (inorganics only) or "J" qualifier were treated as detected concentrations.
- Data qualified as rejected (flagged "R") were not used in the RA.
- Only parent sample results were included in the analysis when field duplicate or split samples were collected.

C3.2.2 Criteria for Selection of Contaminants of Potential Concern for the Human Health Risk Assessment

In accordance with DOE, EPA, and Ecology guidance, factors considered in identifying the COPCs for the study area are as follows:

- Identification of detected chemicals
- Essential nutrients
- Background screening
- Availability of toxicity values for use in calculating CULs.

The COPCs were identified separately for shallow zone and deep zone soil samples from each waste site. Evaluation of the RA data using these criteria is discussed in the following subsections.

C3.2.2.1 Identification of Detected Chemicals

As a conservative measure, all chemicals that were detected at least once in any of the shallow zone or deep zone soil samples were carried to the next step in the COPC selection process. Chemicals that were not detected in any of the soil samples (i.e., 0 percent frequency of detection) were not selected as COPCs.

C3.2.2.1.1 Shallow Zone

The summary statistics for the radiological and nonradiological chemicals detected in shallow zone soil samples are presented in Tables C-3 through C-5.

- **216-B-26 Trench.** A total of 26 nonradiological constituents and four radiological constituents were detected at least once in shallow soil.
- **216-B-46 Crib.** A total of 25 nonradiological constituents and seven radiological constituents were detected at least once in shallow soil.
- **216-B-58-Trench.** A total of 15 nonradiological constituents and 19 radiological constituents were detected at least once in shallow soil.

C3.2.2.2 Deep Zone

The summary statistics for the radiological and nonradiological chemicals detected in deep zone soil samples are presented in Tables C-6 through C-8.

- **216-B-26 Trench.** A total of 33 nonradiological constituents and 23 radiological constituents were detected at least once in deep soil.
- **216-B-46 Crib.** A total of 27 nonradiological constituents and 13 radiological constituents were detected at least once in deep soil.
- **216-B-58-Trench.** A total of 22 nonradiological constituents and 27 radiological constituents were detected at least once in deep soil.

C3.2.2.3 Essential Nutrients

Essential nutrients are those constituents considered essential for human nutrition. Recommended daily allowances are developed for essential nutrients to estimate safe and adequate daily dietary intakes (NAS 1989, *Recommended Dietary Allowances*). Because aluminum, calcium, iron, magnesium, potassium, and sodium are considered to be essential nutrients and have no available toxicity factors, they were excluded from further consideration as COPCs. Even essential nutrients can be harmful to human health and the environment at extremely high concentrations, but the concentrations at the evaluated sites are low enough to be of no concern.

C3.2.2.4 Background Screening

The next criterion for identifying a constituent as one of potential concern was its presence at a concentration higher than naturally occurring levels. Sitewide soil background levels have been established for metals and radiological constituents for the Hanford Site. The statewide soil background level was used as the background level for cadmium. Sitewide and statewide soil background levels are not available for antimony, bismuth, cyanide, nitrite, selenium, sulfate, thallium, Co-60, Pu-239, Tc-99, and tritium. If these metals or radionuclides were detected, they were carried forward into the RA. Because volatile organic compounds, polychlorinated biphenyls (PCB), and semivolatile organic compounds are not naturally occurring in the soils at the Hanford Site, any constituents detected in these fractions also were carried forward into the RA.

The maximum detected concentrations of each metal or radionuclide detected in shallow or deep zone soil were compared to the 90^{th} percentile background value. Summaries of metals and radiological constituents compared to background values for each representative waste site are provided in Tables C-9 through C-11 for shallow-zone soils and Tables C-12 through C-14 for deep-zone soils.

C3.2.2.5 Availability of Toxicity Values

If a toxicity value was not available from a reliable source or an appropriate surrogate could not be identified, then the chemical was not included in the RA. Toxicity values were identified for all COPCs in soil, with the exception of bismuth, general chemical parameters (including ammonium ion, chloride, oil and grease, phosphate, sulfate, sulfide, and total organic carbon). Toxicity values were generally unavailable for general chemical parameters, and tentatively identified compounds (TIC). These constituents are, in general, considered relatively nontoxic (e.g., general chemical parameters) or were detected at a relatively low frequency (e.g., TICs) and were not carried forward into the RA. The exclusion of these constituents could cause risk at the waste sites to be underestimated.

C3.2.2.6 Contaminants of Potential Concern

Table C-15 summarizes the COPCs for the 216-B-26 Trench, the 216-B-46 Crib, and the 216-B-58 Trench.

C3.3 HUMAN EXPOSURE ASSESSMENT

The exposure assessment component of the HHRA identifies the populations that could be exposed; the routes by which these individuals could become exposed; and the magnitude, frequency, and duration of potential exposures. The human exposure assessment includes the following components:

- Discussion of the RESRAD RA methodology
- Development of exposure assumptions for potentially complete exposure pathways
- Calculation of chemical intake for COPCs
- Source of toxicity values.

C3.3.1 Residual Radioactivity Risk Assessment Methodology

The RA for radiological constituents was performed using RESRAD Version 6.21 (ANL 2002, *RESRAD for Windows*). The RESRAD model was used to obtain risk and dose estimates from direct-contact exposure to radiological constituents present in the shallow zone of the BC Cribs and Trenches Area waste sites. The RESRAD model also was used to obtain risk and dose estimates for protecting the groundwater pathway. The results obtained from the RESRAD model for groundwater protection are limited to use for screening purposes only.

C3.3.2 Human Exposure Assumptions

The estimation of exposure requires numerous assumptions to describe potential exposure scenarios. Upper-bound exposure assumptions are used to estimate "reasonable maximum" exposure conditions to provide a bounding estimate on exposure. The exposure assumptions and methodology used to develop soil risk-based CULs for nonradiological constituents are described in Section C.3.3.2.1. The assumptions and methodology used to calculate risk and dose estimates using RESRAD for radiological constituents are described in Section C.3.3.2.2.

C3.3.2.1 Nonradiological Constituents

Exposure assumptions and methodology used for developing the direct-contact CULs under the industrial land-use scenario are provided in WAC 173-340-745.

As discussed in the CSM, groundwater at the waste sites is not used for drinking water purposes. However, exposure assumptions are provided for the groundwater ingestion pathway for the purpose of evaluating the groundwater protection pathway. The exposure assumptions and methodology used for deriving soil concentrations for groundwater protection are provided in WAC 173-340-747.

Exposure estimates for current and future industrial workers are based on the assumption that a 70 kg adult would contact surface soil 146 d/yr over 20 years. For the direct-contact pathway, an incidental soil ingestion rate of 50 mg/day was assumed. For the inhalation pathway, an inhalation rate of 20 m^3/day was assumed. For the groundwater protection pathway, a drinking water ingestion rate of 2 L/day was assumed.

C3.3.2.2 Radiological Constituents

Exposure assumptions and methodology used for developing risk and dose estimates for the industrial and hypothetical Native American subsistence scenarios were obtained from Harris and Harper (1997) and ANL 2002. The scenarios evaluated were selected based on the conceptual exposure model (Figure C-6) and are consistent with the reasonably anticipated future land uses.

The RESRAD model allows the use of site-specific chemical and physical parameters to estimate risk and dose. Site-specific parameters include depth of contamination, depth of clean cover, soil density, volumetric moisture, and chemical-specific distribution coefficients (K_ds). A detailed list of the site-specific input parameters is provided in DOE/RL-2002-42.

An analysis of soil to water partition coefficients (K_ds) was conducted based on several studies prepared for the 200 Areas. The distribution coefficient (K_d) values that were selected for use in the RESRAD modeling are provided in PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Areas Plateau of the Hanford Site*. The "Zone F" category values were used, because this category represents the type of waste that was disposed of in the BC Cribs and Trenches waste sites. The Zone F category is defined as sources with low organics, low salts, and near-neutral conditions.

For radiological constituents, the RESRAD (ANL 2002) output provided current and future simulations of contribution to the risk of groundwater contamination from the movement of vadose contaminants to groundwater. Fate and transport modeling using the *Subsurface Transport Over Multiple Phases* (STOMP) (PNNL-11216, *STOMP -- Subsurface Transport Over Multiple Phases: Application Guide*) code was not conducted, because groundwater protection has been established for all three of the evaluated sites.

Industrial Land-Use Scenario. Exposure estimates for the current and future industrial worker are based on the assumption that a 70 kg adult would be exposed to surface soil 2,000 h/yr (14 percent of the year spent indoors, 9 percent of the year spent outdoors, and 77 percent of the year spent off site) over 30 years. An incidental soil ingestion rate of 100 mg/day and an inhalation rate of 20 m^3/day were assumed. For the groundwater protection pathway, a drinking water ingestion rate of 2 L/day was assumed.

Hypothetical Native American Subsistence Scenario. Exposure assumptions for the Native American subsistence scenario were obtained from Harris and Harper (1997). This study suggests that a traditional Tribal member would lead a moderately active lifestyle, spending 180 d/yr conducting various subsistence activities (e.g., hunting, fishing, and gathering) and spending the full year consuming materials obtained through these activities. In addition, as much as 3.6 h/day could be spent swimming or performing other water-contact activities. This lifestyle would be applied over a 70-year lifetime.

This exposure scenario assumes that radiological contaminants from each waste site will not directly impact the Columbia River. (NOTE: Contaminant transport through movement of groundwater is evaluated in a separate OU.) Therefore, the contaminants from BC Cribs and Trenches Area waste sites currently present in the vadose zone are not expected to have any effect on the Columbia River or impact fish in the river.[1]

C3.3.3 Equations for Soil Cleanup Levels

Soil CULs for nonradionuclide contaminants were obtained from Ecology 94-145, *Cleanup Levels and Risk Calculations Under the Model Toxics Control Act Cleanup Regulation; CLARC, Version 3.1.* Soil CULs were not identified for nonradionuclides that do not have available toxicity data. The following paragraphs provide the equations used to calculate the soil risk-based concentrations under the industrial land-use exposure scenarios for carcinogens and noncarcinogens. The exposure assumptions used to calculate the CULs for each exposure scenario are listed in Table C-16.

Carcinogens. The following equation was used to calculate the WAC 173-340-745, Method C soil CULs for carcinogenic chemicals:

$$Soil\ Concentration\,(mg/kg) = \frac{TR \times BWc \times ATc \times UCF}{CPF_o \times SIR \times ABS_{gi} \times EF \times ED}$$

[1]The fish ingestion pathway in the RESRAD model was turned off.

where

TR = Target risk (= 1.0 E-05) (unitless)
BW = Average body weight over exposure duration (= 70 kg)
AT = Averaging time (= 75 years)
UCF = Unit conversion factor (=1.0 E+06 mg/kg)
CPF = Carcinogenic potency factor (contaminant specific) (kg-day/mg)
SIR = Soil ingestion rate (= 50 mg/day)
ABS = Gastrointestinal absorption fraction (= 1) (unitless)
EF = Exposure frequency (= 0.4) (unitless)
ED = Exposure duration (= 20 years).

Noncarcinogens. The following equation was used to calculate the WAC 173-340-745, Method C soil CULs for noncarcinogenic chemicals:

$$Soil\ Concentration\ (mg/kg) = \frac{THQ \times BW_{nc} \times AT \times UCF \times RfD_{o}}{EF \times ED \times SIR \times ABS_{gi}}$$

where

THQ = Target hazard quotient (= 1) (unitless)
BW = Average body weight over exposure duration (= 70 kg)
AT = Averaging time (= 20 years)
UCF = Unit conversion factor (= 1.0 E+06 mg/kg)
RfD = Reference dose (contaminant specific) (mg/kg-day)
EF = Exposure frequency (= 0.4) (unitless)
ED = Exposure duration (= 20 years)
SIR = Soil ingestion rate (= 50 mg/day)
ABS = Gastrointestinal absorption fraction (= 1) (unitless).

C3.3.4 Equations for Ambient Air Cleanup Levels

Ambient air CULs were calculated for all COPCs. The following paragraphs provide the equations used to calculate the ambient air risk-based concentrations under the industrial land-use exposure scenario for carcinogens and noncarcinogens. The exposure assumptions used to calculate the CULs for each exposure scenario are listed in Table C-16.

Carcinogens. The following equation was used to calculate the WAC 173-340-750, "Cleanup Standards to Protect Air Quality," Method C ambient air CULs for carcinogenic chemicals:

$$Air\ Concentration\ (mg/m^3) = \frac{TR \times BWc \times ATC}{CPF_i \times INH \times ABS_{INH} \times EF \times ED}$$

where

TR = Target Risk (= 1.0 E-05) (unitless)
BW = Average body weight over exposure duration (= 70 kg)
AT = Averaging time (= 75 years)
CPF = Carcinogenic potency factor (contaminant specific) (kg-day/mg)
INH = Inhalation rate (= 20 m^3/day)
ABS = Inhalation absorption fraction (= 1) (unitless)
EF = Exposure frequency (= 1) (unitless)
ED = Exposure duration (= 20 years).

Noncarcinogens. The following equation was used to calculate the WAC 173-340-750, Method C ambient air CULs for noncarcinogenic chemicals:

$$Air\ Concentration\ (mg/m^3) = \frac{THQ \times BW_{nc} \times ATN \times RfDi}{EF \times ED \times INH \times ABS_{inh}}$$

where

THQ = Target hazard quotient (= 1) (unitless)
BW = Average body weight over exposure duration (= 70 kg)
AT = Averaging time (= 20 years)
UCF = Unit conversion factor (= 1.0 E+06 mg/kg)
RfD = Reference dose (contaminant specific) (mg/kg-day)
EF = Exposure frequency (= 1) (unitless)
ED = Exposure duration (= 20 years)
INH = Inhalation rate (= 20 m^3/day)
ABS = Inhalation absorption fraction (= 1) (unitless).

C3.3.5 Equations for Groundwater Cleanup Levels

Groundwater CULs were calculated in accordance with the methodology described in WAC 173-340-720. The following paragraphs provide the equations used to calculate the groundwater risk-based concentrations under the unrestricted land-use exposure scenario for carcinogens and noncarcinogens. The exposure assumptions used to calculate the CULs for each exposure scenario are listed in Table C-17.

Carcinogens. The following equation was used to calculate the WAC 173-340-720, Method B groundwater CULs for carcinogenic chemicals:

$$Groundwater\ Concentration(ug/L) = \frac{TR \times BW \times AT \times UCF}{CPF \times DWIR \times INH \times DWF \times ED}$$

where

TR = Target Risk (= 1.0 E-05) (unitless)
BW = Average body weight over exposure duration (= 70 kg)
AT = Averaging time (= 75 years)
UCF = Unit conversion factor (= 1,000 μg/mg)
CPF = Carcinogenic potency factor (contaminant specific) (kg-day/mg)
DWIR = Soil ingestion rate (= 2 L/day)
INH = Inhalation correction factor (= 1) (unitless)
DWF = Drinking water fraction (= 1) (unitless)
ED = Exposure duration (= 30 years).

Noncarcinogens. The following equation was used to calculate the WAC 173-340-747, Method B groundwater CULs for noncarcinogenic chemicals:

$$Groundwater\ Concentration\ (ug/L) = \frac{THQ \times BW_{nc} \times ATN \times UCF \times RfD_{o}}{DWF \times ED \times DWIR \times INH}$$

where

THQ = Target hazard quotient (= 1) (unitless)
BW = Average body weight over exposure duration (= 70 kg)
AT = Averaging time (= 6 years)
UCF = Unit conversion factor (= 1,000 μg/mg)
RfD = Reference dose (contaminant specific) (mg/kg-day)
DWF = Drinking water fraction (= 1) (unitless)
ED = Exposure duration (= 6 years)
DWIR = Drinking water ingestion rate (= 2 L/day)
INH = Inhalation correction factor (= 1) (unitless).

C3.3.6 Equations for Soil Concentrations Protective of Groundwater

The following paragraphs provide the equations used to calculate the nonradionuclide soil concentrations that will not cause concentrations in groundwater to exceed the groundwater CULs established under WAC 173-340-720, "Ground Water Cleanup Standards." (NOTE: Modeling was used to develop acceptable soil concentrations for radionuclide constituents.) The groundwater concentration (C_w) used in the equation was set equal to the groundwater CUL unless a Federal drinking water maximum contaminant level (MCL) was available. When an MCL was available for a constituent, the lower of the MCL or the groundwater CUL was selected as the groundwater concentration. The three-phase partitioning equation was used to derive soil concentrations protective of groundwater:

$$Cs = C_w \times UCF \times DF \times \left[K_d + \frac{\theta_w + \theta_a \times H'}{\rho_b} \right]$$

where

C_s = calculated soil concentration (mg/kg)
C_w = groundwater CUL established under WAC 173-340-720 (µg/L)
UCF = unit conversion factor (1×10^{-3} mg/µg)
DF = dilution factor (20 unitless)
K_d = distribution coefficient (chemical-specific) (L/kg)
Θ_w = water-filled soil porosity (0.3 mL/mL)
Θ_a = air-filled soil porosity (0.13 mL/mL)
H' = Henry's Law constant (chemical-specific) (dimensionless)
P_b = dry soil bulk density (1.5 kg/L).

When a published K_d was not available, the following equation was used to calculate the coefficient:

$$K_d = K_{oc} \times f_{oc}$$

where

K_d = distribution coefficient (chemical-specific) (L/kg)
K_{oc} = soil organic carbon-water partitioning coefficient (chemical-specific) (mL/g)
F_{oc} = soil fraction of organic carbon (0.001 g/g).

C3.3.7 Sources of Toxicity Values

Toxicity values used to calculate the soil and groundwater CULs were obtained from the following sources.

- The primary source of toxicity values (i.e., cancer potency factors and oral reference doses) is the EPA's Integrated Risk Information System (IRIS) database, available on the Internet at http://www.epa.gov/iris/index.html.

- If a toxicity value was not available from IRIS, toxicity values published in the EPA's Provisional Peer-Reviewed Toxicity Values (PPRTV) available on the Internet at hhtp:/hhpprtv.ornl.gov/index.shtml, the EPA/540/R-97/036, *Health Effects Assessment Summary Tables, FY 1997 Update,* or EPA (2002) were used.

C3.4 RISK ASSESSMENT RESULTS FOR NONRADIOLOGICAL CONSTITUENTS

All nonradiological COPC concentrations were compared to WAC 173-340-745, Method C CULs developed for the direct-contact pathway. Additionally, nonradiological constituents were compared to the WAC 173-340-747, Method B soil concentrations protective of groundwater.

All CULs developed for these waste sites were based on chronic or carcinogenic threats. Each 95 percent UCL or maximum soil concentration, whichever is less, was compared to its respective CUL. WAC 173-340-745 states that carcinogenic risks should be less than 1×10^{-5}

for Method C and concentrations of individual noncarcinogenic constituents that pose a chronic toxic effect to human health should not exceed a hazard quotient (HQ) of 1.0.

The HQ can be back-calculated by dividing the concentration term by its respective noncancer CUL. As described in the previous paragraph, a ratio greater than one suggests a potential for adverse health effects as defined by WAC 173-340-745(5)(b)(iii)(B), "Soil Direct Contact."

Carcinogenic risk is expressed as a probability of developing cancer as a result of lifetime exposure. For a given chemical and route of exposure, excess lifetime cancer risk (ELCR) can be back-calculated by dividing the concentration term by its cancer CUL and multiplying by 1×10^{-5} (for industrial exposure) to estimate the chemical-specific risk. An ELCR that exceeds the target risk threshold of 1×10^{-5} indicates that, as a plausible upper bound, an individual has a one-in-one-hundred-thousand chance of developing cancer as a result of site-related exposure to a carcinogen, over a 75-year lifetime, under the specific exposure conditions at that waste site.

The EPA generally considers action to be warranted at a waste site when cancer risks exceed 1×10^{-4} based on a reasonable maximum exposure (RME) scenario. Action generally is not required for risks falling within 1×10^{-4} to 1×10^{-6}; however, the need for action is judged on a case-by-case basis. Risks of less than 1×10^{-6} generally are not of concern to regulatory agencies. An HQ (the ratio of chemical intake to the reference dose) greater than one indicates that some potential exists for adverse noncancer health effects associated with exposure to the contaminants of concern (OSWER Directive 9285.6-03).

C3.4.1 Comparison Results to WAC 173-340-745, Method C Direct-Contact and WAC 173-340-747, Method B Groundwater Protection Cleanup Levels

The BC Cribs and Trenches Area waste sites are located within the Central Plateau Industrial/Exclusive Zone and were compared to the industrial land-use direct-contact (WAC 173-340-745, Method C and WAC 173-340-747, Method B) groundwater protection CULs.

C3.4.1.1 216-B-26 Trench

Direct Contact. As shown in Table C-18, the maximum detected concentrations[1] for all nonradiological contaminants are less than their respective WAC 173-340-745 CULs.

Groundwater Protection. As shown in Table C-19, the maximum detected concentrations for manganese, uranium, nitrate, and nitrogen in nitrate/nitrite exceed their respective 90th percentile background concentration and the EPC exceeds the WAC 173-340-747 CUL. The EPCs for nitrate (4,090 mg/kg), nitrogen as nitrate and nitrite (1,080 mg/kg), manganese (641 mg/kg), and

[1] Only one shallow zone sample was collected from the 216-B-26 Trench; therefore, the maximum detected concentration was used for comparison.

uranium (57 mg/kg) exceed their respective CULs of 40 mg/kg, 173 mg/kg, 512 mg/kg, and 3.2 mg/kg, respectively.

Three-Part Test. Because the EPCs for nitrate, nitrogen as nitrate and nitrite, manganese, and total uranium were above their respective CUL, the WAC 173-340-740(7)[e], "Compliance Monitoring," three-part test was conducted. Twelve samples were analyzed for nitrate; three samples were reported with concentrations greater than the CUL of 40 mg/kg (concentrations range from 185 mg/kg to 4,090 mg/kg). Twelve samples were analyzed for nitrogen as nitrate and nitrite; three samples were reported with concentrations greater than the CUL of 173 mg/kg (concentrations range from 52 mg/kg to 1,080 mg/kg). Twelve samples were analyzed for total uranium; four samples were reported with concentrations greater than the CUL of 3.2 mg/kg (concentrations range from 6.6 mg/kg to 57 mg/kg). In all cases, sample concentrations were greater than two times the CUL and greater than 10 percent of the sample concentrations exceed the CUL. Based on the results of the WAC 173-340-740(7)[e] three-part test, nitrate, nitrogen as nitrate and nitrite, and total uranium should be considered contaminants of concern (COC) for the groundwater protection pathway and should be further considered in the FS.

The groundwater protection CUL for manganese (65 mg/kg) is less than the Hanford Site background concentration of 512 mg/kg; therefore, the groundwater protection CUL for manganese was adjusted to 512 mg/kg. Only one sample was analyzed for manganese and was reported at a concentration of 641 mg/kg, which is slightly above the background level of 512 mg/kg (but not greater than two times the CUL). Because the groundwater protection CUL for manganese is based on a secondary MCL (0.05 mg/L) to prevent taste/odor/aesthetic problems (manganese can stain plumbing fixtures) and the slight exceedance of the CUL, manganese is not considered a COC for the groundwater protection pathway.

C3.4.1.2 216-B-46 Crib

Direct Contact. As shown in Table C-20, the EPCs for all constituents are less than their respective WAC 173-340-745 CULs.

Groundwater Protection. As shown in Table C-21, the EPCs for cadmium and total uranium exceed their respective WAC 173-340-747 CULs. The EPCs for cadmium (1.1 mg/kg) and uranium (35 mg/kg) exceed their respective CULs of 0.81 mg/kg and 3.2 mg/kg, respectively.

Three-Part Test. EPCs for cadmium and uranium were above their respective CUL; therefore, the WAC 173-340-740(7)[e] three-part test was conducted. The groundwater protection CUL for uranium (1.3 mg/kg) is less than the Hanford Site background concentration of 3.2 mg/kg; therefore, the groundwater protection CUL for uranium was adjusted to 3.2 mg/kg. Ten samples were analyzed for uranium; four samples were reported with concentrations greater than the adjusted CUL of 3.2 mg/kg (concentrations range from 4.4 mg/kg to 35 mg/kg). Uranium was detected in two samples at a concentration greater than two times the CUL (3.2 mg/kg) and four of ten samples analyzed (40 percent) were greater than the CUL of 3.2 mg/kg. Based on the results of the WAC 173-340-740(7)[e] three-part test, total uranium should be considered a COC for the groundwater protection pathway and should be further considered in the FS. The groundwater protection CUL for cadmium (0.69 mg/kg) is less than the Hanford Site background concentration of 0.81 mg/kg; therefore, the groundwater protection CUL for cadmium was adjusted to 0.81 mg/kg. Cadmium was detected in two samples at concentrations greater than the CUL of 0.81 mg/kg (concentrations range from 1.1 mg/kg to 1.5 mg/kg). Cadmium was not detected in any sample at a concentration greater than two times the CUL and two of the nine samples analyzed (22 percent) were slightly greater than the CUL. Because detected concentrations are slightly greater than the adjusted CUL and because these concentrations are detected in the shallow zone, cadmium concentrations are considered naturally occurring and are unlikely to be a groundwater concentration. Therefore, cadmium is not considered a COC for the groundwater protection pathway.

C3.4.1.3 216-B-58 Trench

Direct Contact. As shown in Table C-22, the maximum detected concentrations[1] for all constituents are less than their respective WAC 173-340-745 CULs.

Groundwater Protection. As shown in Table C-23, the maximum detected concentrations for arsenic, selenium, and nitrate exceed their respective WAC 173-340-747 CULs. The EPCs for arsenic (11 mg/kg), selenium (7.4 mg/kg), and nitrate (104 mg/kg) exceed their respective CULs of 6.5 mg/kg, 5.2 mg/kg, and 40 mg/kg, respectively.

Three-Part Test. EPCs for arsenic, selenium, and nitrate were above their respective CUL; therefore, the WAC 173-340-740(7)[e] three-part test was conducted. Fifteen samples were analyzed for selenium; nine samples were reported with concentrations greater than the CUL of 5.2 mg/kg (concentrations range from 5.5 mg/kg to 13 mg/kg). Fifteen samples were analyzed for nitrate; two samples were reported with concentrations greater than the CUL of 40 mg/kg (concentrations range from 208 mg/kg to 255 mg/kg). In both cases, sample concentrations were greater than two times the CUL and greater than 10 percent of the sample concentrations exceed the CUL. Based on the results of the WAC 173-340-740(7)[e] three-part test, selenium and nitrate should be considered COCs for the groundwater protection pathway and should be further considered in the FS.

The groundwater protection CUL for arsenic (0.035 mg/kg) is less than the Hanford Site background concentration of 6.5 mg/kg; therefore, the groundwater protection CUL for arsenic was adjusted to 6.5 mg/kg. Arsenic was detected in 13 samples at concentrations greater than the CUL of 6.5 mg/kg (concentrations range from 6.5 mg/kg to 16 mg/kg). Arsenic was detected in one sample at a concentration greater than two times the CUL (6.5 mg/kg) and 12 of the 15 samples collected (80 percent) were greater than the CUL of 6.5 mg/kg. Although detected concentrations were greater than two times the adjusted CUL, it is less than the WAC 173-340-900, "Model Toxics Control Act – Cleanup," "Tables" (Table 740-1) CUL of 20 mg/kg for unrestricted land use (adjusted for natural background). Because the concentrations of arsenic detected are less than the WAC 173-340-900 (Table 740-1) CUL (20 mg/kg), arsenic concentration is less than the Statewide background for soils and therefore is not considered a COC for the groundwater protection pathway.

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[1]Only two shallow zone samples were collected from the 216-B-58 Trench; therefore, the maximum detected concentration was used for comparison.

C3.4.2 Results of Comparison to Air Cleanup Levels

As shown in Tables C-24 through C-26, all shallow zone soil sample results are less than their respective WAC 173-340-750, Method C ambient air CUL.

C3.5 RISK ASSESSMENT RESULTS FOR RADIOLOGICAL CONSTITUENTS

All radiological COPCs were evaluated under the industrial, hypothetical Native American subsistence, and groundwater protection exposure scenarios. All direct-contact exposure scenarios were evaluated without clean cover material. All scenarios were evaluated with the absence of clean cover, assuming a contaminated zone ranging from 0 m to 4.6 m (0 to 15 ft). Exposure times were carried out to 1,000 years for each waste site.

The following RA results focus on the industrial exposure scenario. The hypothetical Native American subsistence exposure scenario was evaluated to provide a basis of comparison (assuming unrestricted land use) to the industrial exposure scenario.

For the purposes of this RA, the radiation dose limit for each of the exposure scenarios evaluated (industrial and hypothetical Native American) is 15 mrem/yr (OSWER Directive 9200.4-31P, *Radiation Risk Assessment At CERCLA Sites: Q & A* [EPA/540/R-99/006]). This dose limit was developed for members of the public who are unknowingly exposed to radiation.

C3.5.1 Summary of Dose and Risk Estimates for Radiological Constituents

Tables C-27 and C-28 present input parameter values used for the industrial, Native American, and groundwater protection scenario RESRAD modeling. Tables C-29 through C-31 summarize the dose and risk estimates for the industrial exposure scenario, the Native American Subsistence scenario, and the groundwater protection pathway for each of the BC Cribs and Trenches Area waste sites.

For comparison, risk and dose estimates are discussed relative to the following exposure times, which are based on the results of risk framework workshops as documented in the Tri-Parties' response to the Hanford Advisory Board (Klein et al. 2002, "Consensus Advice #132: Exposure Scenarios Task Force on the 200 Area"), as amended.

- 50 yr is the estimated time that the DOE will have an onsite presence.
- 150 yr is the estimated time that institution controls are assumed to be effective.
- Dose estimates are provided for the exposure time when the target dose limit of 15 mrem/yr is achieved.

C3.5.1.1 216-B-26 Trench

Industrial Scenario. As shown in Table C-29, the maximum estimated total industrial scenario dose rate at the 216-B-26 Trench is 3.1 E+05 mrem/yr and the maximum ELCR is 1.0 E+00 at year 0 (i.e., 2004). The ELCR under this exposure scenario is above the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times before year 500. The primary contributors to total dose and risk are Cs-137 and Pu-239.

Native American Subsistence Scenario. As shown in Table C-29, the maximum estimated total industrial scenario dose rate at the 216-B-26 Trench is 4.0 E+06 mrem/yr and the maximum ELCR is 6.0 E+01 at year 0 (i.e., 2004). The ELCR under this exposure scenario is above the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times before year 1,000. The primary contributors to total dose and risk are Cs-137, Sr-90, and Pu-239.

Groundwater Protection. As shown in Table C-29, the maximum estimated total groundwater dose rate at the 216-B-26 Trench is 360 mrem/yr and the maximum ELCR is 1.0 E-03 at year 68. The ELCR is above the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times before year 150. The primary contributor to total dose and risk is Tc-99.

C3.5.1.2 216-B-46 Crib

Industrial Scenario. As shown in Table C-30, the maximum estimated total dose rate at the 216-B-46 Crib is 1.89 E+00 mrem/yr and the maximum ELCR is 4.0 E-05 at year 0 (i.e., 2004). The ELCR under this exposure scenario is within the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times. The primary contributor to total dose is Ra-226.

Native American Subsistence Scenario. As shown in Table C-30, the maximum estimated total dose rate at the 216-B-46 Crib is 2.48 E+01 mrem/yr and the maximum ELCR is 4.0 E-04 at year 50 (i.e., 2004). The ELCR under this exposure scenario is slightly greater the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times. The primary contributors to total dose and risk are Ra-226 and Sr-90.

Groundwater Protection. As shown in Table C-30, the maximum estimated total dose rate at the 216-B-46 Crib is 3.19 E-01 mrem/yr at year 50 and the maximum ELCR is 1.0 E-04 at year 68. The ELCR is within the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times. The primary contributors to total dose and risk are Tc-99 and uranium-234.

C3.5.1.3 216-B-58 Trench

Industrial Scenario. As shown in Table C-31, the maximum estimated total dose rate at the 216-B-58 Trench is 4.6 E+03 mrem/yr and the maximum ELCR is 3.0 E-02 at year 0 (i.e., 2004). The ELCR under this exposure scenario is above the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times before 150 years. The primary contributors to total dose and risk are Co-60, Cs-137, and Pu-239.

Native American Subsistence Scenario. As shown in Table C-31, the maximum estimated total dose rate at the 216-B-58 Trench is 2.1 E+04 mrem/yr and the maximum ELCR is 3.0 E-02 at year 0 (i.e., 2004). The ELCR under this exposure scenario is above the target risk range of

1.0×10^{-4} to 1.0×10^{-6} at all times before 500 years. The primary contributors to total dose and risk are Co-60 and Pu-239.

Groundwater Protection. As shown in Table C-31, the maximum estimated total dose rate at the 216-B-58 Trench is 1.7 mrem/yr and the maximum ELCR is 9.0 E-06 at year 66. The ELCR is within or below the target risk range of 1.0×10^{-4} to 1.0×10^{-6} at all times. The primary contributor to total dose and risk is tritium.

C3.6 UNCERTAINTY ANALYSIS

Several sources of uncertainty affect the overall estimates of ELCR and noncarcinogenic hazards as presented in this HHRA.

C3.6.1 Uncertainty Associated with Sampling and Analysis

Uncertainties associated with sampling and analysis include the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. While the quality assurance/quality control program used in conducting the sampling and analysis reduces errors, it cannot eliminate all errors associated with sampling and analysis.

C3.6.2 Uncertainty Associated with Exposure Assessment

Future soil EPCs were assumed to be equal to existing soil concentrations. This assumption does not account for fate and transport processes likely to occur in the future. For example, ignoring the fact that contaminant soil concentrations will decrease as contaminant mass migrates into the vadose zone will tend to overestimate future soil exposure risks.

In addition, existing soil concentrations are based on sampling results. These results were collected at a limited number of points on each release site, and the sampling may or may not have produced results that are truly representative of the average contaminant concentrations at each site. Risk calculations may be over or under estimated as a result of the limited amount of sampling that was used to estimate mean concentration values.

The estimation of exposure requires many assumptions to describe potential exposure situations. Uncertainties exist regarding the likelihood of exposure, frequency of contact with contaminated media, the concentration of contaminants at exposure points, and the time period of exposure. These tend to simplify and approximate actual waste site conditions. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard. However, risk may be underestimated if an unevaluated exposure pathway (e.g., consumption of contaminated produce by site workers) eventually exists. In addition, risks may be underestimated in the Native American exposure scenario, because the scenario evaluated only exposure to radionuclides.

The WAC 173-340 default exposure assumptions were used to estimate the current and future industrial land-use scenario conservatively. It is unlikely that an industrial worker would work solely at one waste site over a 25-year exposure period. Similarly, it is unlikely that a Native American would reside at any one of the waste sites evaluated over an entire lifetime. The default exposure assumptions for the industrial and hypothetical Native American subsistence land-use scenarios likely overestimate dose and risk at the site.

The RESRAD model was used to evaluate the potential for unacceptable radiation dose impacts at a given waste site. The input parameter values that were used in this model are uncertain, because the future is uncertain and modeling is based on many exposure assumptions. This parameter uncertainty may cause risk to be over or under estimated at a given waste site. All of the uncertainties discussed in this section might cause errors in dose estimates in the same way they may cause errors in risk estimates.

C3.6.3 Uncertainty Associated with Toxicity Assessment

The toxicological database also was a source of uncertainty. The EPA has outlined some of the sources of uncertainty in the RA guidance for the *Superfund* (EPA/540/1-89/002). These sources may include or result from the extrapolation from high to low doses and from animals to humans; the species, gender, age, and strain differences in a toxin's uptake, metabolism, organ distribution, and target site susceptibility; and the human population's variability with respect to diet, environment, activity patterns, and cultural factors.

C3.6.4 Uncertainty Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancerous adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically.

C4.0 ECOLOGICAL RISK ASSESSMENT

This section provides the methodology and results of the SLERA for the BC Cribs and Trenches Area waste sites. The SLERA assesses the potential impacts of past releases on wildlife, assuming the absence of remediation. The objectives of this SLERA are (1) to evaluate the potential for ecological exposures from the contaminants and (2) to identify the likelihood of adverse impacts on the ecosystem.

C4.1 ECOLOGICAL RISK ASSESSMENT GUIDANCE

The DOE, EPA, and Ecology have published guidance documents for performing ERAs. The procedures used for this ERA are consistent with those described in the following documents:

- EPA/630/R-95/002F, *Guidelines for Ecological Risk Assessment*
- EPA/540-R-97-006, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (Interim Final)*
- EPA/910-R-97-005, *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund*
- EPA/630/R-92/001, *Framework for Ecological Risk Assessment*
- DOE/STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (developed by the Biota Dose Assessment Committee ([BDAC])
- DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*
- DOE/RL-2001-54, *Central Plateau Ecological Evaluation*, Draft B
- WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures."

C4.2 OVERVIEW OF THE ECOLOGICAL RISK ASSESSMENT APPROACH

The general approaches for conducting an ERA in accordance with the DOE, EPA, and Ecology guidance are presented in DOE/RL-2001-54. The following subsections summarize the site-specific framework for the BC Cribs and Trenches Area waste sites.

C4.2.1 Nonradionuclides

This ERA is structured in a way that is consistent with EPA (EPA/540/R-97/006, EPA/910/R-97/005, and EPA/630/R-95/002Fa) and Ecology ERA guidance documents. This ERA, which uses conservative screening values provided by Ecology (WAC-173-340-900), corresponds to Step 1 (preliminary problem formulation) and Step 2 (screening) of the EPA guidance (EPA/540/R-97/006). The SLERA (Step 2) intentionally is conservative and serves to eliminate from further evaluation analytes and waste sites that obviously do not pose a risk to the environment despite the SLERA's bias toward overestimating risk. The SLERA is used to determine whether further evaluation (i.e., baseline ecological RA) or remedial actions may be necessary.

C4.2.2 Radionuclides

The EPA and Ecology guidance documents do not address radionuclides; therefore, the potential effects of surface residual contamination on terrestrial receptors were evaluated using the terrestrial radionuclide screening levels presented in DOE-STD-1153-2002, developed by the DOE and BDAC. The BDAC has been assisting the DOE in developing a technical standard that provides a graded approach for evaluating radiation doses to biota. The technical standard has been approved by the DOE for assessing the ecological effects of radiological exposure when conducting ERAs.

The DOE's graded approach for evaluating radiation doses to biota consists of a three-step process designed to guide a user from an initial, conservative general screening to a more rigorous analysis using site-specific information (if needed) and is consistent with the eight-step EPA approach for conducting ERAs. The DOE recommends the following three-step process:

1. Assembling radionuclide concentration data and knowledge of sources, receptors, and routes of exposure for the area to be evaluated

2. Applying a general screening methodology that provides limiting radionuclide concentration values (i.e., the biota concentration guide [BCG], proposed by the BDAC in DOE-STD-1153-2002) in soil

3. If needed, conducting risk evaluation through site-specific screening, site-specific analysis, or an actual site-specific biota dose assessment within an ecological risk framework, similar to that recommended in EPA/630/R-95/002F.

Any of the steps in the graded approach may be used at any time. To avoid confusion with the eight-step EPA process, the DOE's steps for evaluating risks posed by radionuclides are referred to as Levels 1 through 3 throughout the remainder of this document. These levels roughly coincide with Step 2 of EPA's process. This SLERA uses Level 1, part of Level 2 (e.g., mean concentrations), and a simplified Level 3 to assess the risks to wildlife potentially exposed to radionuclides at the BC Cribs and Trenches Area waste sites.

The BCGs contained in the technical standard guidance include conservative screening concentrations that are judged to be protective of the most sensitive terrestrial organisms tested (e.g., small mammals), assuming a terrestrial animal dose threshold of 0.1 rad/day and a terrestrial plant threshold of 1 rad/day. The BCGs were developed from dose-response relationships for chronic reproductive effects (Jones et al. 2003, "Principles and Issues in Radiological Ecological Risk Assessment"). Each radionuclide-specific BCG represents the limiting radionuclide concentration in environmental media (i.e., soil, sediment, or water) that would not exceed the DOE's established or recommended dose standards for biota protection. Therefore, surface soil concentrations of less than the BCGs are not considered to pose a threat to terrestrial receptors.

C4.3 ORGANIZATION OF THE ECOLOGICAL RISK ASSESSMENT

The remainder of this assessment has been organized into the following subjects to identify the potential for ecological risk.

- **SLERA:** Presents the methodologies and results of the SLERA (Section C4.4).
- **Characterization of uncertainty:** Identifies uncertainties in the assumptions used to estimate risk to ecological endpoint species (Section C4.5).
- **Evaluation of ecological significance:** Discusses the significance of the results of the SLERA; collectively considers the results of the SLERA in light of the assumptions and inherent limitations of the analyses (Section C4.6).
- **Conclusions/recommendations:** Summarizes the conclusions and recommendations based on the results of the SLERA (Section C4.7).

C4.4 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

This ERA is consistent with the eight-step ERA process developed for the *Superfund* program in EPA-540-R-97-006. The process starts with a SLERA, which is considered to follow Steps 1 and 2 of the EPA ERA guidance (EPA-540-R-97-006). The primary purposes of Steps 1 and 2 are to identify analytes and sites with minimal potential for ecological risk quickly and efficiently and to eliminate them from further evaluation. The first step, preliminary problem formulation, is considered a conservative, qualitative determination of whether ecological receptors, habitat, and exposure pathways are present at a site. The information provided in Section C2.0 satisfies Step 1 and indicates that a potential for complete ecological exposure pathways exists at the BC Cribs and Trenches Area waste sites. Step 2, ecological risk-based screening, is a conservative assessment of whether constituents detected at the waste sites are present at concentrations that are sufficiently high to indicate a potential for risk at the waste sites and to support a decision to proceed to a baseline ERA (Steps 3 through 7 of the eight-step ERA process) or discuss remedial alternatives. Therefore, results of a SLERA are used to determine which of the following recommendations can be made:

- No further ecological investigations at the waste site
- Continuation of the RA process at the next level (baseline ERA)
- Take a removal or remedial action to address potential risks.

C4.4.1 Screening-Level Ecological Risk Assessment Methodology

The SLERA process used is as described in DOE/RL-2001-54. For nonradionuclides, the SLERA is consistent with EPA's ERA guidance (EPA/540/R-97/006 and EPA/630/R-95/002F) and the process outlined in WAC 173-340-7493. The methodology for the radionuclide ecological evaluation follows the process developed by the BDAC in DOE-STD-1153-2002.

During the SLERA, site media concentrations are compared to conservative risk-based media concentrations that are anticipated to be without ecological consequences. These risk-based media concentrations were obtained from Ecology (for nonradionuclides) and DOE (for radionuclides) sources.

C4.4.1.1 Nonradionuclides

Under WAC 173-340, a distinction is made between commercial/industrial and all other types of land use. For a commercial or industrial property, only potential exposure pathways to wildlife need to be considered (i.e., soil biota and plants are not intended to be protected because of the site land use), while plants and soil biota must be considered along with wildlife at sites designated for other land uses. According to WAC 173-340-200, "industrial properties" are those that are or have been characterized by or are to be committed to traditional industrial uses such as processing or manufacturing of materials; marine terminal and transportation areas and facilities; fabrication, assembly, treatment, or distribution of manufactured products; or storage of bulk materials, that are zoned for industrial use by a city or county. The BC Cribs and Trenches Area waste sites are in an area considered to be industrial property, which will remain unchanged in the future because of land-use restrictions. Therefore, each area was screened only against the wildlife screening values provided in WAC 173-340-900, Table 749-3. These values represent conservative "no observed adverse effect level" (NOAEL)-based screening levels that are protective of wildlife populations and include protection for potential chemical exposure through the food chain. Surface soil concentrations 0 to 3 m (0 to 15 ft bgs) are compared with these wildlife-screening values.

C4.4.1.2 Radionuclides

The WAC 173-340-7490 regulations and the screening values presented in WAC 173-340-900, Table 749-3, address only nonradionuclide chemicals. Because radionuclide chemicals are present at the Hanford Site, the BCG screening values provided in DOE-STD-1153-2002 have been used to screen radionuclides. The default terrestrial wildlife BCGs are soil concentrations that have been calculated for a hypothetical small mammal and use high-end exposure assumptions that include, but are not limited to, the following: small body weight, high ingestion rate compared to body weight, continuous exposure to radiation from all directions, 100 percent area use, and high incidental soil ingestion rates. The model also assumes that a dose of 1 rad/day is protective of terrestrial plants while a dose of 0.1 rad/day is protective of terrestrial animals. This dose is based on preventing effects to the most sensitive species tested.
Each radionuclide-specific BCG represents the limiting radionuclide concentration in environmental media that would not exceed the DOE's recommended dose standards for biota. These BCG values represent conservative NOAEL-based screening levels assumed to be protective of wildlife populations and include protection for potential radionuclide exposures through the food chain. In addition, because the effects of exposure to multiple radionuclides can be additive, all radionuclide fractions (maximum concentration/BCG) have been summed as follows:

$$\text{Total hazard index} = \sum (\text{maximum radionuclide concentration/BCG}).$$

If the total risk estimate (sum of all fractions) is less than 1.0, the ecological risk is considered acceptable and the evaluation for radionuclides is complete. The guidance uses three levels to evaluate the potential risk to ecological receptors, with the first level being the most conservative. Level 1 uses maximum detected concentrations rather than the 95 percent UCL recommended by WAC 173-340 regulations for the initial screening. Level 2 uses a screening of the arithmetic mean concentrations against BCGs. Therefore, in accordance with DOE-STD-1153-2002, the maximum and mean radionuclide concentrations have been compared to their respective BCGs, and all fractions have been summed to determine if the sum is less than 1.0. The following lists outline the primary assumptions used for estimating a BCG at each level of the SLERA for radionuclides, in accordance with the DOE guidance:

Level 1 Assumptions

1. Source in soil is infinite (i.e., nondepleting) and terrestrial wildlife are exposed to uniform radionuclide doses.
2. Exposed species have infinitely small mass, which results in an overestimation of the external dose rate for finite-sized organisms. In addition, internal dose is maximized by assumption of infinitely large internal organs.
3. Wildlife species are immersed 100 percent of the time in the waste site soils.
4. Ten percent of the total diet for the wildlife species is from incidental ingestion of soil.
5. Initial exposure parameters (e.g., bioaccumulation factors, ingestion rate) are specifically chosen to produce very conservative BCGs, and some of these factors may range over several orders of magnitude, depending on biotic and abiotic features at the sites (DOE-STD-1153-2002).
6. The 100 percent area use factor is applied (i.e., the wildlife species are expected to forage and reside exclusively at each waste site).
7. Effect limits are based on the protection of the most radiologically sensitive species tested.
8. Maximum detected surface soil concentration is used in the BCG comparisons.

Level 2 Assumptions

For this SLERA, Level 2 assumptions are the same as Level 1 assumptions, except that mean surface soil concentrations are used for the BCG comparisons rather than the maximum detected concentration (includes all except Level 1, Item 8).

Level 3 Assumptions

All of the conservative assumptions are the same as the Level 1 assumptions, except the following changes are made to No. 4, part of No. 5, and No. 8:

4. Because the model is based on exposure to small mammals (e.g., mice), the highest incidental soil ingestion rates for any rodent (2.8 percent) reported in EPA 1993, *Wildlife Exposure Factors Handbook*, are applied in place of the default value of 10 percent.

5. Less conservative bioaccumulation factors (i.e., high-end rather than upper bound) from empirical studies reported in the DOE technical standard are applied. Specifically, the 95th percentile animal-to-soil bioaccumulation value (20 for Cs-137) from a kinetic/allometric method was applied (DOE-STD-1153-2002; Higley et al. 2003, "A Probabilistic Approach to Obtaining Limiting Estimates of Radionuclide Concentration in Biota").

8. As in Level 2, mean surface soil concentrations are used for the BCG comparisons.

Threatened and endangered species are of high concern at the Hanford Site. As mentioned in Section C2.1.3, two federally protected species have been observed at the Hanford Site: the Aleutian Canada goose (*Branta canadensis leucopareia*) and the bald eagle (*Haliaeetus leucocephalus*). As migratory birds, these species also are protected under the *Migratory Bird Treaty Act* (1918). Both of these species depend on the habitats along the river corridor for food sources and are rarely seen in the Central Plateau. No plants, invertebrates, amphibians, reptiles, or mammals are listed by the Federal or Washington State threatened and endangered species programs. Considering this, exposure of any Federal- or state-listed wildlife species is not likely to occur at the BC Cribs and Trenches Area waste sites.

C4.4.2 Analysis and Results

Samples were collected from boreholes and were analyzed for volatile and semivolatile organic compounds, inorganics (metals), total petroleum hydrocarbon (TPH), general chemistry, and radionuclides. Samples also were collected for physical properties analysis, and data were validated in accordance with the project's quality assurance plan. Soil samples were collected during the RI at depths ranging from 0 to 4.6 m (0 to 15 ft) bgs. Consistent with EPA recommendations for a SLERA, all chemicals that are detected at least once in any of the shallow zone soil samples were evaluated in the SLERA. The analyses and results of the screening are presented separately in the following subsections for nonradionuclides and radionuclides.

C4.4.2.1 Nonradionuclides

For each waste site, the lower of the 95 percent UCL and the maximum detected concentration for each nonradionuclide constituent was screened against the wildlife screening values presented in WAC 173-340-900, Table 749-3, to determine if any chemical concentrations exceeded their respective screening values. The results of this screening for each representative waste site are presented in Tables C-32 through C-34. None of the COPCs exceeded the screening values.

C4.4.2.2 Radionuclides

The maximum (Level 1) and mean (Level 2) detected concentration of each radionuclide was screened against the BCGs proposed by the BDAC (DOE-STD-1153-2002). The results of this screening also are presented in Tables C-32 through C-34. None of the radionuclides exceeded the screening values, with the exception of Cs-137 and Sr-90 in the 216-B-26 Trench and the 216-B-58 Trench.

C4.5 CHARACTERIZATION OF UNCERTAINTY

Uncertainties are inherent in all aspects of an ERA. The nature and magnitude of uncertainties depend on the amount and quality of available data, the degree of knowledge concerning site conditions, and the assumptions made to perform the ERA. Uncertainties in ERA methods can result in either understating or overstating ecological risks. Risk estimates are subject to uncertainty from a variety of sources, including the following:

- Sampling, analysis, and data evaluation
- Fate and transport estimation
- Exposure estimation
- Toxicological data
- Risk characterization.

C4.5.1 Sampling, Analysis, and Data Evaluation

Uncertainty associated with sampling and analysis includes inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, biased sampling, and heterogeneity of the sample matrix. The quality assurance/quality control program used in the investigation reduces these errors, but it cannot eliminate all errors associated with sampling and analysis. The degree to which sample collection and analyses reflect real soil concentrations partly determines the reliability of the risk estimates. Sample data used for the SLERA were generated from samples collected at known or suspected source areas. Because exposure to wildlife is not likely to be limited solely to higher concentration areas, risk estimates for these areas may be conservatively high.

C4.5.2 Fate and Transport Estimation

This SLERA makes simplifying assumptions about the environmental fate and transport of contaminants of ecological concern; specifically, that no chemical loss, daughter product ingrowth, or transformation occurred. These assumptions ignore the possibility of exposure to toxic daughter products and transformation products and therefore may cause an underestimation of risk. This assessment also assumes that the chemical concentrations detected in surface soil remain constant during the assessed exposure duration. In cases where natural attenuation and degradation processes are high, the analytical data chosen to represent soil concentrations may overstate actual long-term exposure levels. For example, this SLERA does not account for the decay of radionuclides over time; therefore, future exposure and risk from radionuclides at these waste sites will decrease.

C4.5.3 Exposure Estimation

The estimation of exposure requires many assumptions to describe potential exposure situations. Uncertainties exist regarding the likelihood of exposure, frequency of contact with contaminated media, the concentration of contaminants at exposure points, and the time period of exposure. The assumptions used tend to simplify and approximate actual site conditions and may overestimate or underestimate actual risks. In general, these assumptions are intended to be conservative and yield an overestimate of true risk or hazard.

For nonradionuclides, the EPCs used in the exposure assessment were the lower of the 95 percent UCL of the mean constituent concentration or the maximum detected concentration. The EPC was intended to provide a high-end estimate of actual exposure at the site because the potential receptors are assumed to be exposed to the 95 percent UCL or maximum detected constituent concentration for the entire duration of exposure. As the data indicate, constituent concentrations in many samples were significantly less than the 95 percent UCL or maximum detected concentration. The EPCs were assumed to remain constant for the duration of exposure (i.e., the physical, chemical, or biological processes that could reduce chemical concentrations or changes in the bioavailability of soil constituents over time have not been factored into the estimate of the EPCs). Use of this conservative assumption may overestimate exposure to receptor species.

The EPCs used for radionuclides in the SLERA were the mean constituent concentration at each waste site. Because of the mobility of the potential terrestrial wildlife receptors, sampling at known or suspected contamination areas, and the lower quality foraging habitats at the waste sites relative to other nearby areas, the mean should be considered as a conservative exposure concentration for measuring population-level effects. Although the mean serves as a good indicator of the actual risks to terrestrial wildlife populations, individual organisms (particularly less mobile organisms) could be exposed to higher concentrations.

Many of the waste sites originally were constructed at depths of 3 m (10 ft) or more and have subsequently been backfilled with clean soil. The depth of the clean material on the waste sites varies; however, depths are generally greater than 3 m (10 ft) bgs. Data used in this SLERA were collected at soil locations to depths of 4.6 m (15 ft) bgs. Because most wildlife exposures occur in the upper 0.6 m (2 ft) of soil, the data used serve as a conservative estimate of exposure and may overstate the actual risks.

Area use and temporal use factors were not applied (i.e., wildlife receptors are assumed to reside and exclusively forage at each investigation area). Because most wildlife species are highly mobile, wildlife are unlikely to use only the waste sites. Use of this conservative assumption likely overestimates exposure to most potential receptor species.

C4.5.4 Toxicological Data

Toxicological data for wildlife often are limited for many contaminants. Most wildlife toxicity information is generated by laboratory studies with selected test species. These studies frequently evaluate domestic animals under controlled laboratory conditions, with few tests involving native wildlife. Basic toxicity information can be extrapolated to native species in the wild, but consideration must be given to the species involved and specific site conditions. The standard screening levels used in this SLERA were not calculated for receptor species that could occur at the waste sites. Depending on whether wildlife species at the site are less or more sensitive to the contaminants of concern than the default species in Ecology and DOE guidance, the actual risk may be overestimated or underestimated.

The BCGs in DOE-STD-1153-2002 are based on a 0.1 rad/day limit for terrestrial wildlife and a terrestrial plant threshold of 1 rad/day. This limit is based on the protection of populations of the most radiosensitive species tested (primarily reptiles and small mammals), which likely overestimates the risk to most terrestrial wildlife (although some species could be more sensitive to radionuclide exposure). In addition, because some of the constituents detected at the waste sites did not have available screening levels on which to quantify risks, these constituents could not be evaluated. In general, most of the constituents that have no available toxicity data are considered less toxic, because most of the toxicological literature focuses on those constituents considered more toxic to ecological receptors. However, omission of contaminants without toxicity data may underestimate risk.

C4.6 EVALUATION OF ECOLOGICAL SIGNIFICANCE

Step 1 (preliminary problem formulation) of the ERA process revealed that ecological receptors and sufficient habitat are present or potentially present at the BC Cribs and Trenches Area waste sites. The results of Step 2 (ecological risk-based screening) are provided in Tables C-32 through C-34 and indicate that none of the screening values have been exceeded, except for Cs-137 and Sr-90 at the 216-B-26 Trench and 216-B-58 Trench. Because of the limited area of the trenches, the industrial nature of the surrounding area, and the fact that the contaminants are covered by clean soil, no significant ecological impact is anticipated.

C4.7 CONCLUSIONS/RECOMMENDATIONS

This SLERA assesses the potential impacts on terrestrial wildlife from past releases to soil at the BC Cribs and Trenches Area waste sites and was conducted in accordance with DOE, EPA, and Ecology guidance. The resulting characterization of potential risk is expected to provide enough information that informed decisions can be made about these waste sites. The primary decision for which the results of the screening ecological RA provide input is whether to address any areas and site-related constituents at the waste sites, because of the potential threat to the environment. Therefore, the results of a SLERA are used to determine which of the following recommendations can be made:

- No further ecological investigations at the waste site
- Continuation of the RA process at the next level
- Proceed with a removal or remedial action.

Based on the nature and extent of constituent concentrations observed during the waste site investigation and considering ecosystem characteristics, the following conclusions are made:

- On the basis of considering the background concentrations for metals at the Hanford Site and the screening levels for nonradionuclides, soil concentrations for nonradionuclides are not considered high enough to pose unacceptable risk to terrestrial wildlife at any of the BC Cribs and Trenches Area waste sites evaluated.

- Radionuclide levels in soil do not exceed available Level 1 and 2 screening concentrations for terrestrial wildlife at the BC Cribs and Trenches Area waste sites with the exception of Cs-137 and Sr-90 at the 216-B-26 Trench and 216-B-58 Trench.

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Figure C-1. Location of the BC Cribs and Trenches Area Area Waste Sites South of the 200 East Area.

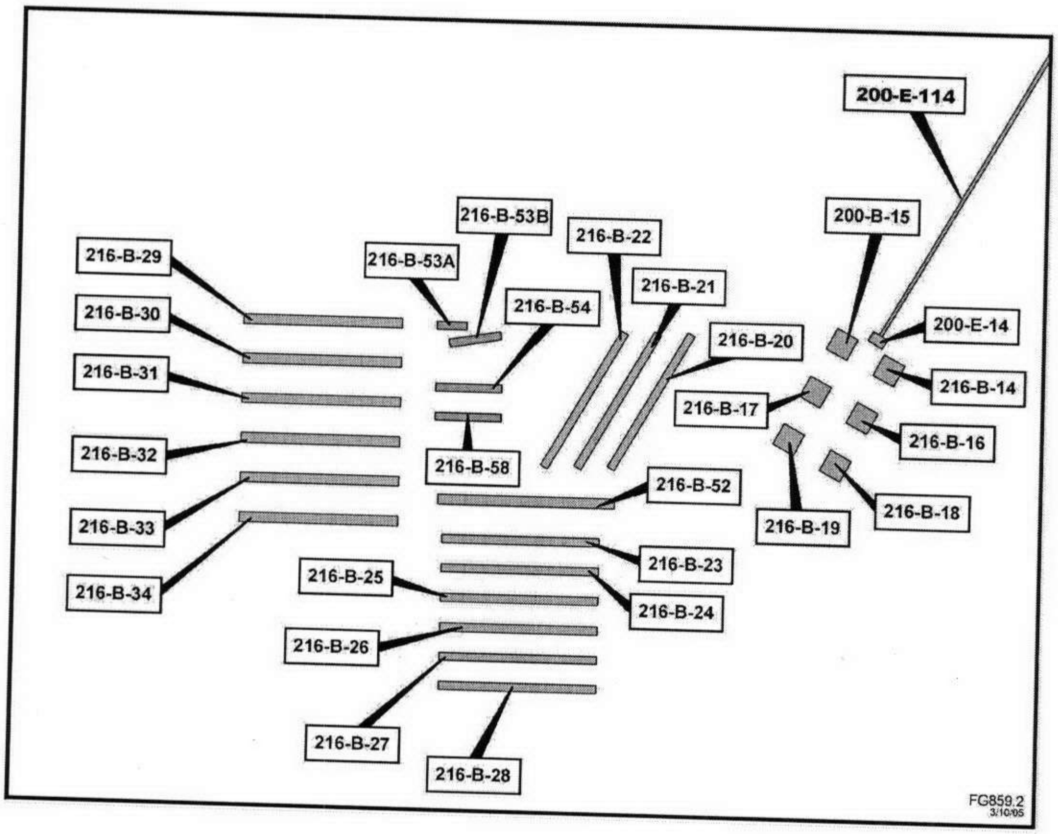

Figure C-2. 216-B-46 Crib Contaminant Distribution Model.

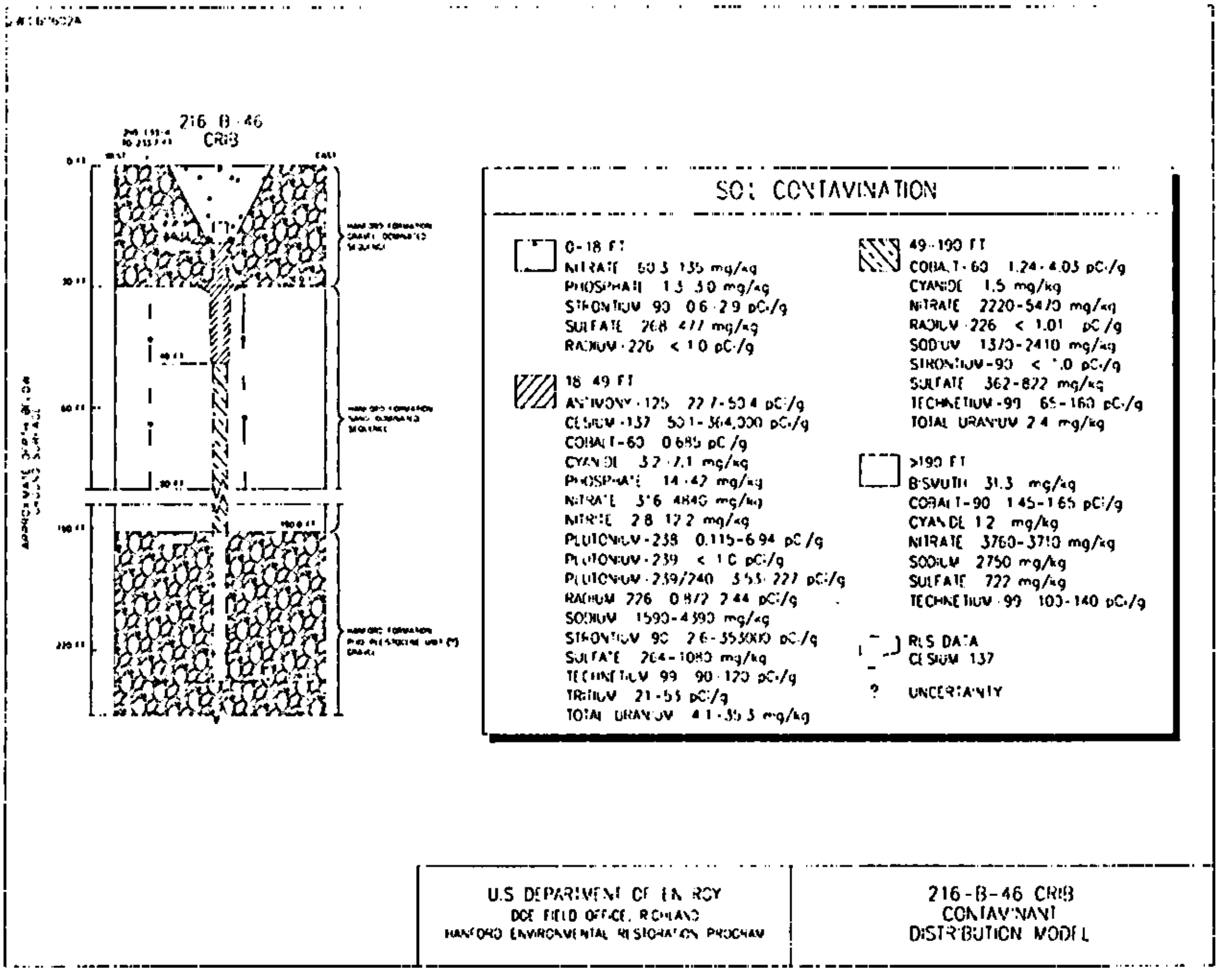

Figure C-3. 216-B-58 Trench Contaminant Distribution Model of Contaminants of Potential Concern (Middle of Trench).

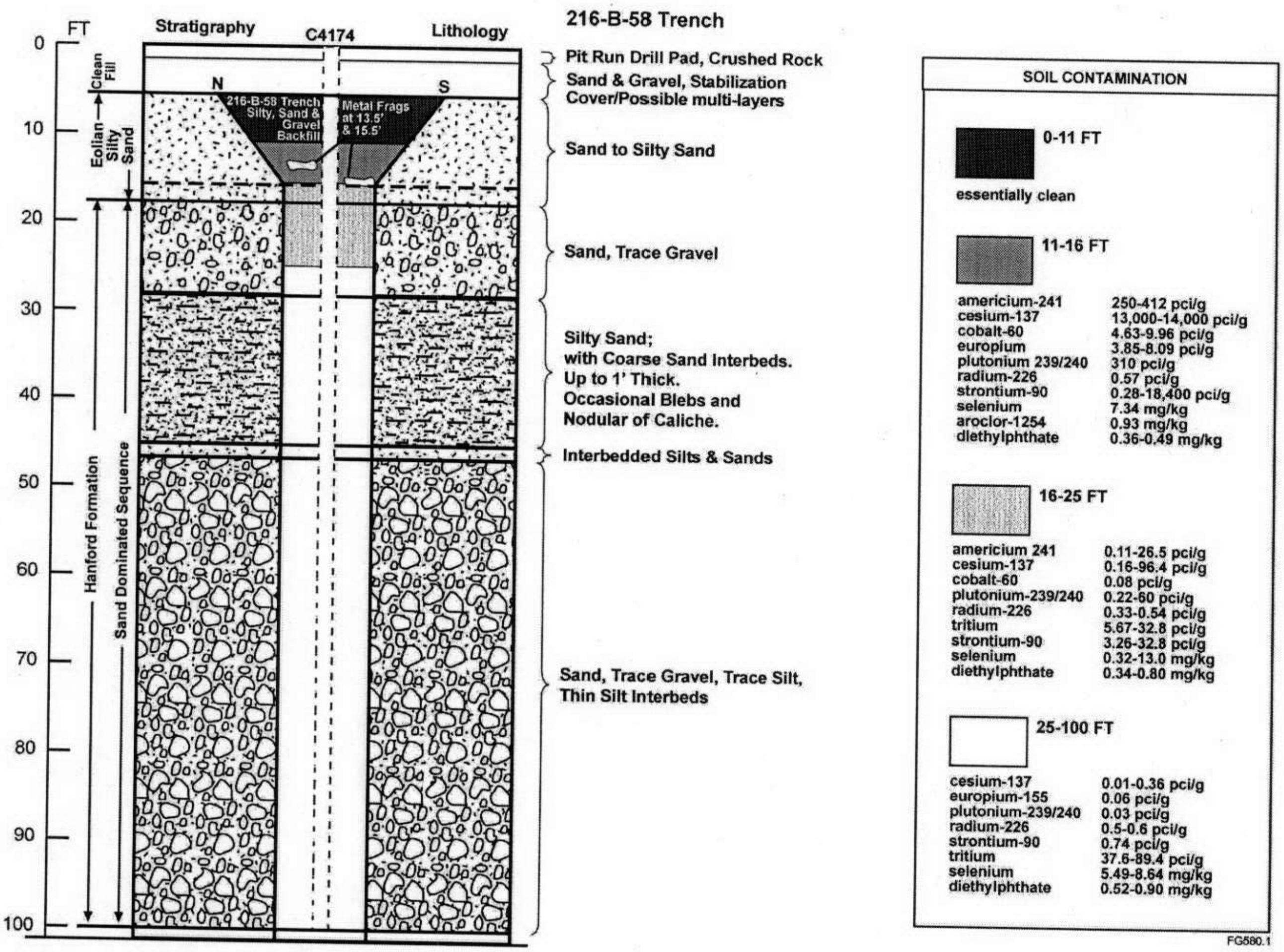

Figure C-4. 216-B-58 Trench Contaminant Distribution Model of Contaminants of Potential Concern (West End of Trench).

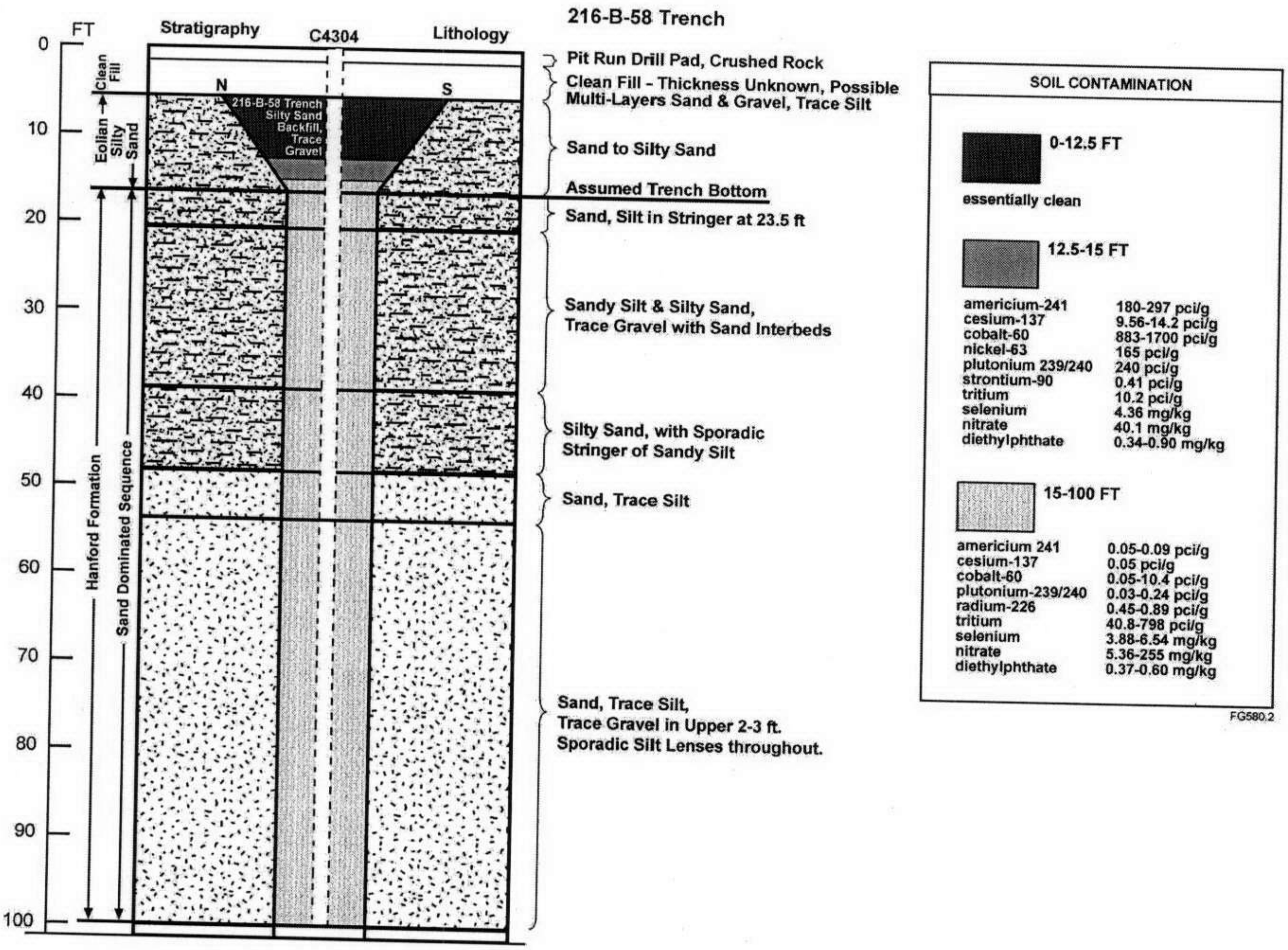

Figure C-5. 216-B-26 Trench Contaminant Distribution Model of Contaminants of Potential Concern.

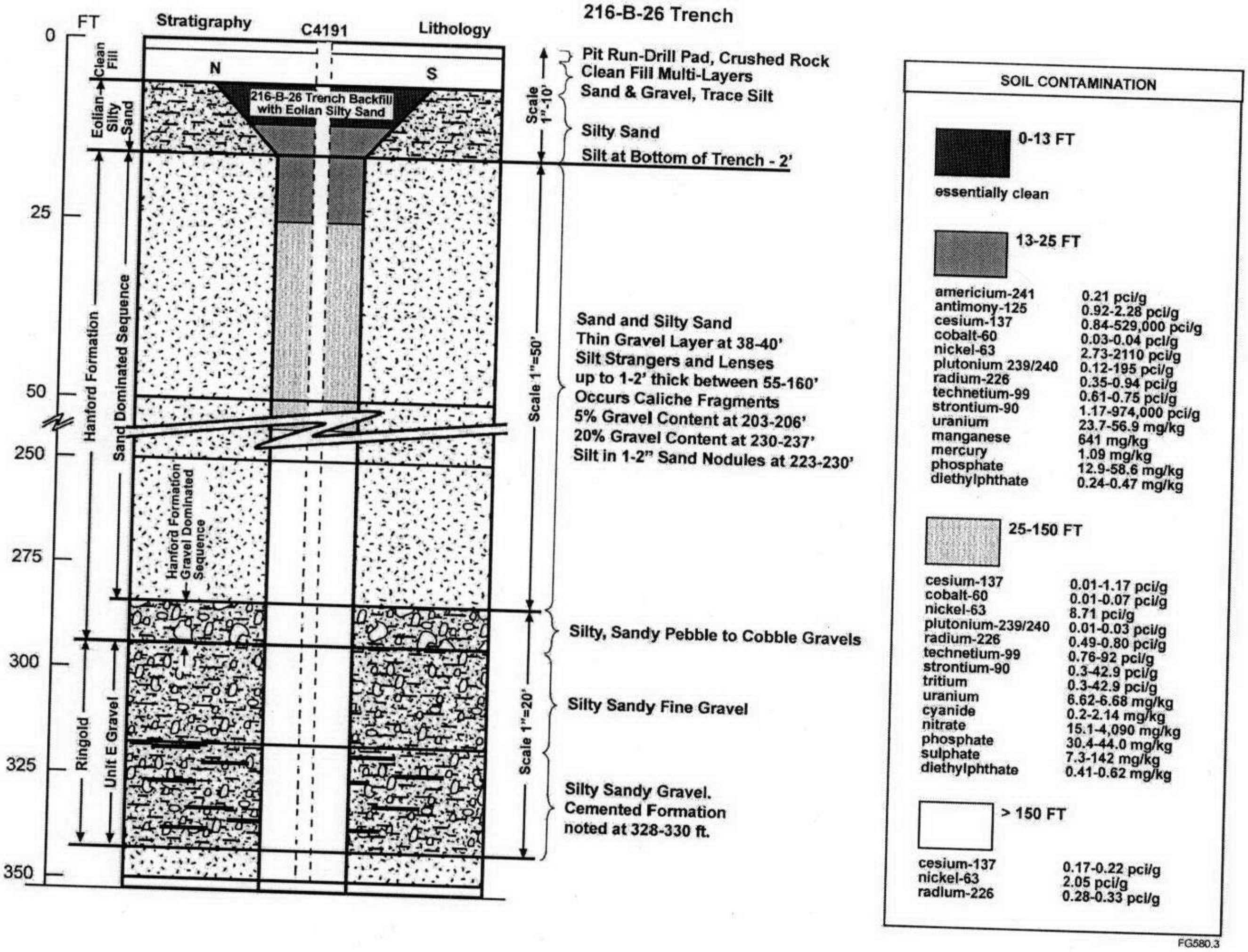

Figure C-6. Conceptual Exposure Model for the BC Controlled Area Waste Sites.

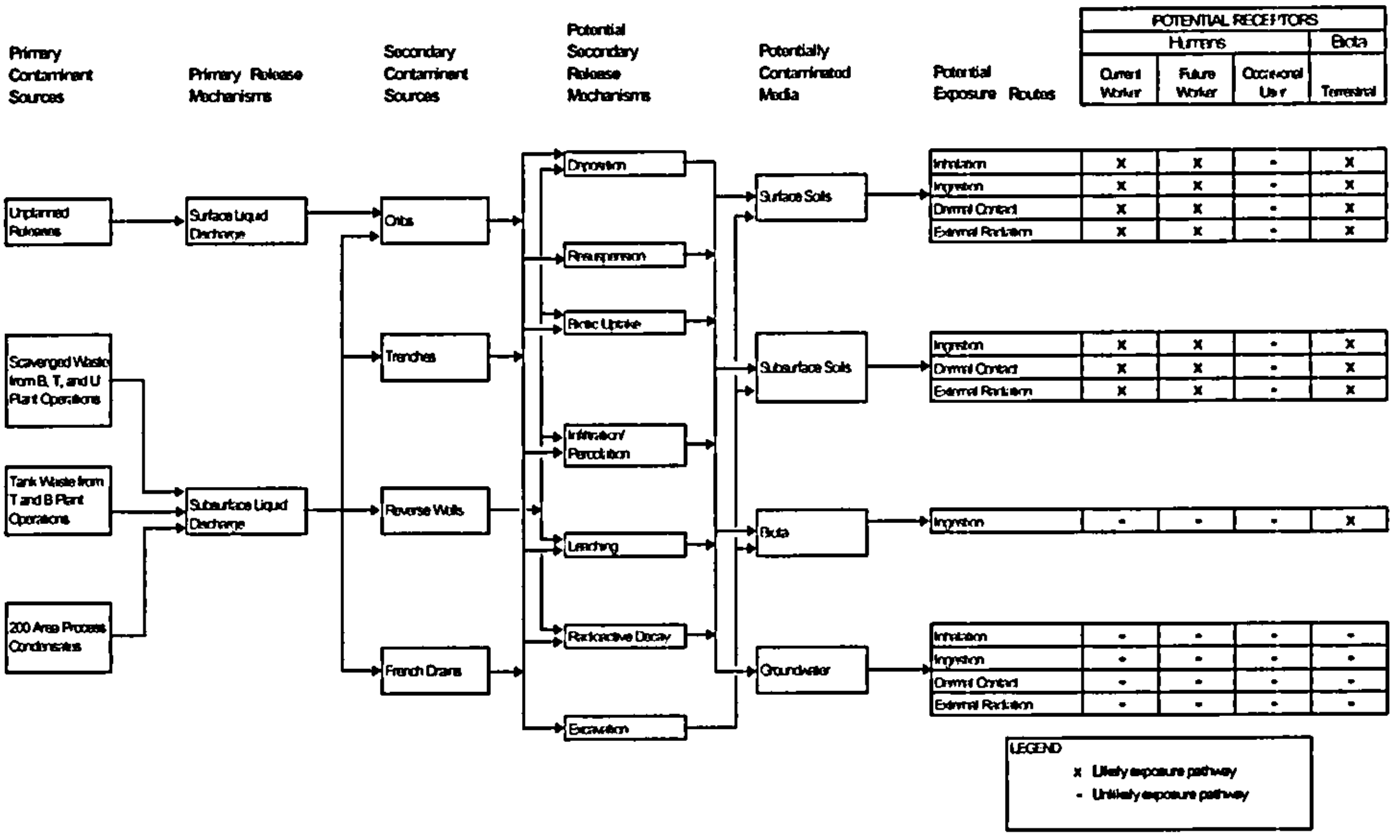

Table C-1. BC Cribs and Trenches Area Representative Site Summary. (4 Pages)

Waste Site	Waste Site Configuration, Construction, and Purpose	Site Discharge History (WIDS)	Contaminant Inventory (DOE/RL-96-81)							Effluent Volume (m^3)	Soil Pore Volume (m^3)	Eff Vol + Pore Vol	Rationale
			Total U (kg)	Total Pu (g)	Tc-99* (Ci)	Cs-137 (Ci)	Sr-90 (Ci)	Ferro-cyanide (kg)	Nitrate (kg)				
216-B-46	The 216-B-46 Crib consists of four 1.2 m (4-ft)-diameter x 1.2 m (4-ft) long concrete culverts, buried vertically with centers spaced 4.6 m (15 ft) apart in a 9.1 x 9.1 x 4.6 m deep (30- x 30- x 15-ft deep) excavation. The depth to the top of contamination is 5.5 m (18 ft). Located approximately 140 m (460 ft) from the BY Tank Farm tanks and within the assembly of 216-B-43 through 216-B-50 Cribs.	Scavenged TBP Waste Stream Tank Farm/U Plant: 1955. The site received scavenged URP supernatant waste from the 221-U Building over a 4-month period in 1955. The waste cascaded through the BY Tank Farm tanks before being discharged to the crib. The waste was originally bismuth phosphate/ lanthanum fluoride metal wastes from 221-B.	190	20.0	32.6	88.9	631	4,000	1,200,000	6,700	9,730	0.68	Investigated in 1991 as part of the 200-BP-1 OU under DOE/RL-88-32; characterization is described in the 200-BP-1 RI Report (DOE/RL-92-70). Contaminant Distribution Sample data confirm that the bottom of the waste site is about 5.5 m (18 ft) bgs. Maximum contaminant concentrations were detected near the bottom of the crib at a depth of 5.5 m (18 ft) and generally decreased with depth. Most of the contamination detected was within a zone extending from the bottom of the crib to 49 ft. With exception of Tc-99 and nitrate, little contamination was detected greater than 14.9 m (49.0 ft). Tc-99 concentration is 120 pCi/g at depths greater than 14.9 m (49 ft). Because contamination starts below 4.6 m (15 ft) bgs, human health risks from direct exposure and ecological risks are not anticipated. However, significant contamination exists just below the bottom of the crib that could pose risk to intruders.

Table C-1. BC Cribs and Trenches Area Representative Site Summary. (4 Pages)

Waste Site	Waste Site Configuration, Construction, and Purpose	Site Discharge History (WIDS)	Contaminant Inventory (DOE/RL-96-81)							Effluent Volume (m^3)	Soil Pore Volume (m^3)	Eff Vol + Pore Vol	Rationale
			Total U (kg)	Total Pu (g)	Tc-99* (Ci)	Cs-137 (Ci)	Sr-90 (Ci)	Ferro-cyanide (kg)	Nitrate (kg)				
216-B-26	The 216-B-26 Trench is a backfilled unlined ditch. Waste site dimensions are 153 x 3 x 5.4 m deep (500 x 10 x 18 ft deep). Includes 2.4 m (8 ft) of overburden. The depth to the top of contamination is 5.8 m (19 ft). However, RLS logging of the C4191 borehole through the trench indicated contamination at approximately 3.7 m (12 ft) bgs. Located in the BC Cribs and Trenches Area and within the assembly of 216-B-23 through 216-B-28 and 216-B-52 Trenches.	Scavenged TBP Waste Stream Tank Farm B, BX, BY: 1956-1957. The site received scavenged bismuth phosphate waste from URP process waste in the 221-U Building. The waste cascaded through the BY Tank Farm tanks before being discharged to the trench.	590 More than rep site	2.5 Less than rep site	28.6 Similar to rep site	438 More than rep site	475 Less than rep site	3,100 Less than rep site	800,000 Less than rep site	5,880 Less than rep site	13,390	0.44 Less than rep site	The 216-B-26 Trench is analogous to the 216-B-46 Crib as indicated by process history, contaminant inventory, effluent volume received, and expected nature and vertical extent of contamination: 1. Received the same waste stream as 216-B-46 Crib; therefore, the contaminant types are expected to be very similar 2. Site construction is similar to 216-B-46 Crib despite 216-B-26 being a trench rather than a crib; both are unlined near-surface liquid disposal sites 3. Waste was received from the same source (221-U Building) 4. Both sites are located in 200 East Area; the geology of the two sites is similar 5. The vertical extent of contamination is expected to be similar based on evidence from similar sites investigated (216-B-43 – 216-B-50 Cribs) 6. Risks are expected to be similar to 216-B-46 Crib; because the top of the contamination is about 3.7 m (12 ft) bgs, human health and ecological risks are expected in the 0 to 4.6 m (0 to 15-ft) zone; risks to intruders may be associated with high contamination at the bottom of the waste site as evidenced by similar risk at 216-B-46 Crib. 7. The relative effluent volume discharged to this trench suggests that contaminant inventory in the vadose zone may pose a threat to groundwater, similar to 216-B-46 Crib. Slightly more than half the relative volume of effluent was sent to the 216-B-26 Trench; this suggests that contaminants remaining in the vadose may not have been flushed through the trench and concentrations may exceed those found in 216-B-46 Crib, which was found to pose a threatundwater.

Table C-1. BC Cribs and Trenches Area Representative Site Summary. (4 Pages)

Waste Site	Waste Site Configuration, Construction, and Purpose	Site Discharge History (WIDS)	Contaminant Inventory (DOE/RL-96-81)							Effluent Volume (m^3)	Soil Pore Volume (m^3)	Eff Vol + Pore Vol	Rationale
			Total U (kg)	Total Pu (g)	Tc-99* (Ci)	Cs-137 (Ci)	Sr-90 (Ci)	Ferro-cyanide (kg)	Nitrate (kg)				
216-B-26 (cont)													to groundwater. This implies that groundwater protection is needed at this waste site, as it is at 216-B-46 Crib. 8. Generally received equivalent or greater contaminant inventory than 216-B-46 Crib. The 216-B-26 Trench received higher inventories of uranium and Cs-137 supporting the need for groundwater protection. The 216-B-26 Trench was sampled in 2003. Contaminant Distribution is as follows. Sample data revealed that the bottom of the waste site is near 4.5 m (13 ft) bgs. The bulk of the contamination was observed at this depth. Maximum Cs-137: 529,000 pCi/g at 4.0 – 4.7 m (13 – 15.5 ft) bgs. Maximum Sr-90: 974,000 pCi/g at the same depth. Maximum Pu-239/240: 195 pCi/g at the same depth. Maximum total uranium: 56.9 mg/kg at the same depth. Technetium-99 and nitrate were observed deeper in the vadose zone. Maximum Tc-99: 92 pCi/g at about 30.5 m (100 ft) bgs. Maximum nitrate: 4,090 mg/kg at the same depth. Because contamination starts above 4.6 m (15 ft) bgs, human health risks from direct exposure risks are anticipated. Significant contamination exists just below the bottom of the trench that could pose a reisk to intruders. In addition, contamination located deeper in the vadose zone poses a potential threat to groundwater. Risks associated with this site imply that groundwater protection is required and that alternatives should consider protection against inadvertent intruders.

Table C-1. BC Cribs and Trenches Area Representative Site Summary. (4 Pages)

Waste Site	Waste Site Configuration, Construction, and Purpose	Site Discharge History (WIDS)	Contaminant Inventory (DOE/RL-96-81)							Effluent Volume (m^3)	Soil Pore Volume (m^3)	Eff Vol + Pore Vol	Rationale
			Total U (kg)	Total Pu (g)	Tc-99* (Ci)	Cs-137 (Ci)	Sr-90 (Ci)	Ferro-cyanide (kg)	Nitrate (kg)				
216-B-58	The 216-B-58 Trench is 60 m (200 ft) long x 3.0 m (10 ft) wide and 3.0 m (10 ft) deep. It was divided into eight 8 m (25 ft) sections by earthen dams that were 1.5 m (5 ft) high and 0.1 m (0.3 ft) wide at their top. A corrugated 1.22 m (4 ft) diameter perforated pipe runs the length of the trench except for the western 8 m (25 ft) section. The depth to the top of contamination is 3.6 m (12 ft). Located in the BC Cribs and Trenches Area and within the assembly of 216-B-53A through 216-B-58 Trenches.	300 Area Laboratory Waste Liquid wastes from the 300 Area laboratory facilities were trucked to this trench from 1965 to 1967.	9.1	6.7	~0	4.40	5.55	--	10	413	5,640	0.073	Investigated in 2003. Contaminant Distribution Sampling confirms that the bottom of the waste site is about 4.1 m (13.5) bgs. The bulk of the contamination is in the 4.1 to 4.9 m (13.5 to 16 ft) bgs zone. The predominant contaminant is Cs-137. A maximum Cs-137 concentration of 14,600 pCi/g was detected at a depth of about 4.3 m (14 ft) bgs. At 8.1 m (26.5 ft) bgs, the concentration was 69.9 pCi/g. A maximum Pu-239/240 concentration of 310 pCi/g was detected at about 4.3 m (14 ft) bgs. Barium concentration peaks at about 7.3 m (24 ft) bgs (87 mg/kg). Selenium concentration peaks at about 5.8 m (19 ft) bgs (7.3 mg/kg). Because contamination begins at depths shallower than 4.6 m (15 ft) bgs, human health risks from direct exposure and ecological risks are anticipated. This contamination also presents a risk to potential intruders. Minor concentrations of mobile contaminants suggest that risk to groundwater may be minor.

*BHI-01496, *Groundwater/Vadose Zone Integration Project Hanford Soil Inventory Model.*
DOE/RL-88-32, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-1 Operable Unit, Hanford Site, Richland, Washington.*
DOE/RL-92-70, *Phase I Remedial Investigation Report for 200-BP-1 Operable Unit, Vols. 1 and 2*, Rev. 0.
DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations.*
Waste Information Data System, Hanford Site database.

bgs = below ground surface.
OU = operable unit.
RI = remedial investigation.
RLS = radionuclide logging system.
TBP = tributyl phosphate.
TRU = transuranic (waste materials contaminated with more than 100 nCi/g of transuranic materials having half-lives longer than 20 years)
URP = Uranium Recovery Process.
WIDS = *Waste Information Data System.*

Table C-2. Summary of Soil Samples Included in the Human Health Risk Assessment, BC Cribs and Trenches Area. (2 Pages)

Exposure Area	Station ID	Sample ID	Depth Interval (ft)	Date Collected	Comment
216-B-58 Trench	C4174	B17RT0	11–13.5	December 6, 2003	Shallow
216-B-58 Trench	C4174	B17RT3	17.5–20	December 6, 2003	Deep
216-B-58 Trench	C4174	B17RT8	22.5–25	December 7, 2003	Deep
216-B-58 Trench	C4174	B17RT9	22.5–25	December 7, 2003	Deep
216-B-58 Trench	C4304	B17RV3	35–37.5	December 18, 2003	Deep
216-B-58 Trench	C4174	B17RV5	27.5–300	December 7, 2003	Deep
216-B-58 Trench	C4174	B17RV8	35–37.5	December 8, 2003	Deep
216-B-58 Trench	C4174	B17RW1	52.5–55	December 9, 2003	Deep
216-B-58 Trench	C4174	B17RW4	97.5–100	December 10, 2003	Deep
216-B-58 Trench	C4304	B17RX0	12.5–15	December 17, 2003	Shallow
216-B-58 Trench	C4304	B17RX4	17.5–20	December 17, 2003	Deep
216-B-58 Trench	C4304	B17RX9	22.5–25	December 17, 2003	Deep
216-B-58 Trench	C4304	B17RY1	27.5–300	December 17, 2003	Deep
216-B-58 Trench	C4304	B17T00	52.5–55	December 18, 2003	Deep
216-B-58 Trench	C4304	B17T03	97.5–100	December 22, 2003	Deep
216-B-58 Trench	C4174	B183L4	13.5–16	December 6, 2003	Shallow
216-B-26 Trench	C4191	B183L6	13–15.5	December 9, 2003	Shallow
216-B-26 Trench	C4191	B183L9	17.5–20	December 11, 2003	Deep
216-B-26 Trench	C4191	B183M1	22.5–25	December 12, 2003	Deep
216-B-26 Trench	C4191	B183M4	27.5–30	December 13, 2003	Deep
216-B-26 Trench	C4191	B183M6	27.5–30	December 13, 2003	Deep
216-B-26 Trench	C4191	B183M7	36–38.5	December 13, 2003	Deep
216-B-26 Trench	C4191	B183M9	52.5–55	December 14, 2003	Deep
216-B-26 Trench	C4191	B183N1	97.5–100	December 17, 2003	Deep
216-B-26 Trench	C4191	B183N4	147.5–150	December 18, 2003	Deep
216-B-26 Trench	C4191	B183N6	197.5–200	December 22, 2003	Deep
216-B-26 Trench	C4191	B183N8	247.5–356	December 30, 2003	Deep
216-B-26 Trench	C4191	B183P2	292–295	December 30, 2003	Deep
216-B-26 Trench	C4191	B183P3	338–340.5	January 13, 2004	Deep
216-B-46 Crib	299-E33-299	B015P3	3–6	December 10, 1999	Shallow
216-B-46 Crib	299-E33-310	B015N1	3–6	December 2, 1991	Shallow
216-B-46 Crib	299-E33-311	B015Q7	3.5–6	January 7, 1992	Shallow
216-B-46 Crib	299-E33-310	B015N5	8–10.5	December 2, 1991	Shallow
216-B-46 Crib	299-E33-299	B015P7	8.5–11	December 11, 1999	Shallow
216-B-46 Crib	299-E33-311	B015Q9	9–12	January 7, 1992	Shallow
216-B-46 Crib	299-E33-310	B015N7	15–17.5	December 3, 1991	Deep
216-B-46 Crib	299-E33-299	B015P5	19–21	December 13, 1999	Deep
216-B-46 Crib	299-E33-311	B015R5	19–21.5	January 9, 1992	Deep
216-B-46 Crib	299-E33-310	B015N9	27–29.5	December 4, 1991	Deep

Table C-2. Summary of Soil Samples Included in the Human Health Risk Assessment, BC Cribs and Trenches Area. (2 Pages)

Exposure Area	Station ID	Sample ID	Depth Interval (ft)	Date Collected	Comment
216-B-46 Crib	299-E33-311	B015R7	27–29.5	January 10, 1992	Deep
216-B-46 Crib	299-E33-299	B015Q1	30–32.5	December 16, 1999	Deep

ID = identification number.

Table C-3. Summary of Statistics for Shallow Zone Soils from the 216-B-26 Trench.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result
CONV	Chloride	mg/kg	1	1	100%	--	--	0.55	0.55
CONV	Fluoride	mg/kg	1	1	100%	--	--	0.45	0.45
CONV	Nitrate	mg/kg	1	1	100%	--	--	7.1	7.1
CONV	Nitrite	mg/kg	1	1	100%	--	--	0.32	0.32
CONV	Nitrogen in nitrite and nitrate	mg/kg	1	1	100%	--	--	4.9	4.9
CONV	Phosphate	mg/kg	1	1	100%	--	--	19	19
CONV	Sulfate	mg/kg	1	1	100%	--	--	5.1	5.1
CONV	Total organic carbon	mg/kg	1	1	100%	--	--	895	895
METAL	Aluminum	mg/kg	1	1	100%	--	--	7,110	7,110
METAL	Bismuth	mg/kg	1	1	100%	--	--	233	233
METAL	Calcium	mg/kg	1	1	100%	--	--	8,980	8,980
METAL	Chromium	mg/kg	1	1	100%	--	--	7.1	7.1
METAL	Copper	mg/kg	1	1	100%	--	--	20	20
METAL	Hexavalent chromium	mg/kg	1	1	100%	--	--	0.61	0.61
METAL	Iron	mg/kg	1	1	100%	--	--	37,900	37,900
METAL	Lead	mg/kg	1	1	100%	--	--	4.3	4.3
METAL	Magnesium	mg/kg	1	1	100%	--	--	6,080	6,080
METAL	Manganese	mg/kg	1	1	100%	--	--	641	641
METAL	Mercury	mg/kg	1	1	100%	--	--	0.070	0.070
METAL	Nickel	mg/kg	1	1	100%	--	--	11	11
METAL	Potassium	mg/kg	1	1	100%	--	--	784	784
METAL	Silver	mg/kg	1	1	100%	--	--	0.24	0.24
METAL	Sodium	mg/kg	1	1	100%	--	--	898	898
METAL	Uranium	mg/kg	1	1	100%	--	--	57	57
METAL	Vanadium	mg/kg	1	1	100%	--	--	101	101
METAL	Zinc	mg/kg	1	1	100%	--	--	65	65
RAD	Cesium-137	pCi/g	1	1	100%	--	--	529,000	529,000
RAD	Nickel-63	pCi/g	1	1	100%	--	--	2,110	2,110
RAD	Plutonium-239/240	pCi/g	1	1	100%	--	--	195	195
RAD	Strontium-90	pCi/g	1	1	100%	--	--	974,000	974,000

CONV = conventional parameter. RAD = radiological.

Table C-4. Summary of Statistics for Shallow Zone Soils from the 216-B-46 Crib. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Detected Result	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
METAL	Aluminum	mg/kg	6	6	100%	--	--	3,220	4,720	3,933	4,519	4,413	4,413	Normal
METAL	Antimony	mg/kg	6	1	17%	4.0	8.9	5.7	5.7	3.3	5.6	4.6	5.6	Log Normal
METAL	Arsenic	mg/kg	6	6	100%	--	--	1.0	2.7	1.9	2.8	2.4	2.4	Normal
METAL	Barium	mg/kg	6	6	100%	--	--	44	71	62	73	70	70	Normal
METAL	Beryllium	mg/kg	6	6	100%	--	--	0.21	0.44	0.29	0.38	0.36	0.38	Log Normal
METAL	Cadmium	mg/kg	6	2	33%	0.60	1.3	1.1	1.5	0.75	2.0	1.1	1.5	Max Detect
METAL	Calcium	mg/kg	6	6	100%	--	--	5,070	7,750	6,312	7,224	7,087	7,224	Log Normal
METAL	Chromium	mg/kg	6	6	100%	--	--	4.0	6.7	5.4	6.6	6.3	6.3	Normal
METAL	Cobalt	mg/kg	6	4	67%	7.1	8.7	5.5	8.2	5.9	8.2	7.3	7.3	Normal
METAL	Copper	mg/kg	6	6	100%	--	--	7.0	12	9.7	12	11	11	Normal
METAL	Iron	mg/kg	6	6	100%	--	--	9,530	14,000	11,688	13,357	13,097	13,357	Log Normal
METAL	Lead	mg/kg	6	6	100%	--	--	2.7	5.7	4.2	5.5	5.1	5.1	Normal
METAL	Magnesium	mg/kg	6	6	100%	--	--	2,480	3,400	2,933	3,284	3,231	3,231	Normal
METAL	Manganese	mg/kg	6	6	100%	--	--	174	267	240	280	270	267	Max Detect
METAL	Mercury	mg/kg	6	1	17%	0.050	0.050	0.060	0.060	0.031	0.045	0.043	0.045	Log Normal
METAL	Nickel	mg/kg	6	6	100%	--	--	4.5	10	7.8	11	9.5	9.5	Normal
METAL	Potassium	mg/kg	6	6	100%	--	--	720	1,250	955	1,143	1,106	1,143	Log Normal
METAL	Sodium	mg/kg	6	4	67%	132	132	186	263	173	452	245	245	Normal
METAL	Thallium	mg/kg	6	1	17%	0.39	0.42	0.60	0.60	0.27	0.45	0.40	0.45	Log Normal
METAL	Uranium	mg/kg	5	2	40%	0.30	0.70	0.84	1.7	0.67	6.7	1.3	1.7	Max Detect
METAL	Vanadium	mg/kg	6	6	100%	--	--	19	29	23	27	26	27	Log Normal
METAL	Zinc	mg/kg	6	4	67%	20	22	21	31	21	38	28	28	Normal
RAD	Cesium-137	pCi/g	6	4	67%	0.030	0.030	0.061	0.20	0.094	1.4	0.16	0.20	Max Detect
RAD	Gross alpha	pCi/g	6	5	83%	3.0	3.0	4.7	7.0	5.3	12	6.9	6.9	Normal
RAD	Gross beta	pCi/g	6	4	67%	32	36	27	38	28	41	35	35	Normal
RAD	Potassium-40	pCi/g	6	6	100%	--	--	12	14	13	14	14	14	Normal
RAD	Radium-226	pCi/g	6	6	100%	--	--	0.68	0.95	0.88	0.98	0.96	0.95	Max Detect
RAD	Strontium-90	pCi/g	6	5	83%	0.040	0.040	0.060	0.45	0.14	1.1	0.26	0.45	Max Detect
RAD	Thorium-228	pCi/g	6	6	100%	--	--	0.0074	0.010	0.0085	0.0094	0.0093	0.0094	Log Normal
SVOC	Benzoic acid	mg/kg	4	1	25%	1.7	1.8	0.041	0.041	0.67	242,824	1.2	0.041	Max Detect

Table C-4. Summary of Statistics for Shallow Zone Soils from the 216-B-46 Crib. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Detected Result	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
SVOC	Bis(2-ethylhexyl) phthalate	mg/kg	4	2	50%	0.35	0.35	0.042	0.049	0.11	3.0	0.20	0.049	Max Detect
SVOC	Di-n-butylphthalate	mg/kg	4	2	50%	0.35	0.35	0.096	0.096	0.14	0.28	0.19	0.096	Max Detect

95UCL = 95th upper confidence level.
EPC = exposure point concentration.
Max Detect = maximum detection.
RAD = radiological.
SVOC = semivolatile organic compound.

Table C-5. Summary of Statistics for Shallow Zone Soils from the 216-B-58 Trench. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result
CONV	Ammonium ion	mg/kg	2	2	100%	--	--	0.29	0.44
CONV	Chloride	mg/kg	2	2	100%	--	--	4.0	4.6
CONV	Fluoride	mg/kg	2	1	50%	1.2	1.2	2.7	2.7
CONV	Nitrate	mg/kg	2	2	100%	--	--	3.7	40
CONV	Nitrogen in nitrite and nitrate	mg/kg	2	2	100%	--	--	1.1	12
CONV	Sulfate	mg/kg	2	1	50%	5.0	5.0	11	11
CONV	Sulfide	mg/kg	2	1	50%	22	22	33	33
CONV	Oil and grease	mg/kg	2	1	50%	709	709	1,350	1,350
METAL	Arsenic	mg/kg	2	2	100%	--	--	6.6	8.8
METAL	Barium	mg/kg	2	2	100%	--	--	67	87
METAL	Chromium	mg/kg	2	2	100%	--	--	4.1	4.8
METAL	Nickel	mg/kg	2	2	100%	--	--	7.8	11
METAL	Selenium	mg/kg	2	2	100%	--	--	4.4	4.7
RAD	Americium-241	pCi/g	1	1	100%	--	--	0.080	0.080
RAD	Cesium-137	pCi/g	2	2	100%	--	--	0.34	14
RAD	Cobalt-60	pCi/g	1	1	100%	--	--	1,700	1,700
RAD	Neptunium-237	pCi/g	1	1	100%	--	--	0.010	0.010
RAD	Nickel-63	pCi/g	1	1	100%	--	--	165	165
RAD	Plutonium-238	pCi/g	2	2	100%	--	--	0.13	20
RAD	Plutonium-239/240	pCi/g	2	2	100%	--	--	2.0	240
RAD	Potassium-40	pCi/g	2	2	100%	--	--	16	16
RAD	Radium-226	pCi/g	1	1	100%	--	--	0.57	0.57
RAD	Radium-228	pCi/g	1	1	100%	--	--	1.2	1.2
RAD	Thorium-228	pCi/g	2	2	100%	--	--	1.2	1.5
RAD	Thorium-230	pCi/g	2	2	100%	--	--	0.37	0.40
RAD	Thorium-232	pCi/g	2	2	100%	--	--	0.89	1.2
RAD	Strontium-90	pCi/g	2	2	100%	--	--	0.28	0.41
RAD	Tritium	pCi/g	1	1	100%	--	--	10	10
RAD	Uranium-233/234	pCi/g	2	2	100%	--	--	0.12	0.74

Table C-5. Summary of Statistics for Shallow Zone Soils from the 216-B-58 Trench. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result
RAD	Uranium-235	pCi/g	2	2	100%	--	--	0.020	0.13
RAD	Uranium-238	pCi/g	2	2	100%	--	--	0.14	0.58
SVOC	Diethylphthalate	mg/kg	2	1	50%	0.22	0.22	0.36	0.36
VOC	Acetone	mg/kg	2	1	50%	0.0050	0.0050	0.052	0.052

CONV = conventional parameter.
RAD = radiological.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

Table C-6. Summary of Statistics for Deep Zone Soils from the 216-B-26 Trench. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Concentration	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
CONV	Ammonium ion	mg/kg	11	8	73%	0.25	0.26	0.27	7.6	2.5	40	3.9	7.6	Max Detect
CONV	Chloride	mg/kg	12	10	83%	2.5	2.6	0.55	24	4.6	9.5	7.9	9.5	Log Normal
CONV	Cyanide	mg/kg	12	2	17%	0.13	0.20	0.26	2.1	0.28	0.45	0.59	0.45	Log Normal
CONV	Fluoride	mg/kg	12	1	8%	1.1	1.2	0.45	0.45	0.56	0.58	0.57	0.45	Max Detect
CONV	Nitrate	mg/kg	12	10	83%	2.9	2.9	4.3	4,090	379	14,947	986	4,090	Max Detect
CONV	Nitrite	mg/kg	12	1	8%	3.0	3.1	0.32	0.32	1.4	2.0	1.6	0.32	Max Detect
CONV	Nitrogen in nitrite and nitrate	mg/kg	12	10	83%	0.17	0.17	0.29	1,080	101	57,974	261	1,080	Max Detect
CONV	Phosphate	mg/kg	12	4	33%	2.6	2.7	14	59	11	66	20	59	Max Detect
CONV	Sulfate	mg/kg	12	11	92%	5.0	5.0	5.1	142	31	92	57	92	Log Normal
CONV	Total organic carbon	mg/kg	12	12	100%	--	--	38	895	232	489	356	489	Log Normal
METAL	Aluminum	mg/kg	1	1	100%	--	--	7,110	7,110	7,110	--	--	7,110	Max Detect
METAL	Bismuth	mg/kg	1	1	100%	--	--	233	233	233	--	--	233	Max Detect
METAL	Calcium	mg/kg	1	1	100%	--	--	8,980	8,980	8,980	--	--	8,980	Max Detect
METAL	Chromium	mg/kg	12	2	17%	2.6	3.0	7.1	8.9	2.5	3.8	3.8	3.8	Log Normal
METAL	Copper	mg/kg	12	8	67%	4.6	4.8	6.7	20	7.4	13	10.0	13	Log Normal
METAL	Hexavalent chromium	mg/kg	12	1	8%	0.20	0.23	0.61	0.61	0.15	0.19	0.22	0.19	Log Normal
METAL	Iron	mg/kg	1	1	100%	--	--	37,900	37,900	37,900	--	--	37,900	Max Detect
METAL	Lead	mg/kg	12	1	8%	5.8	12	4.3	4.3	5.3	5.9	5.7	4.3	Max Detect
METAL	Magnesium	mg/kg	1	1	100%	--	--	6,080	6,080	6,080	--	--	6,080	Max Detect
METAL	Manganese	mg/kg	1	1	100%	--	--	641	641	641	--	--	641	Max Detect
METAL	Mercury	mg/kg	12	4	33%	0.88	1.00	0.070	1.4	0.58	1.0	0.76	0.76	Normal
METAL	Nickel	mg/kg	12	12	100%	--	--	9.6	18	12	13	13	13	Log Normal
METAL	Potassium	mg/kg	1	1	100%	--	--	784	784	784	--	--	784	Max Detect
METAL	Silver	mg/kg	12	1	8%	0.97	2.0	0.24	0.24	0.84	1.1	0.96	0.24	Max Detect
METAL	Sodium	mg/kg	1	1	100%	--	--	898	898	898	--	--	898	Max Detect
METAL	Uranium	mg/kg	12	4	33%	0.49	1.00	6.6	57	10	267	20	57	Max Detect
METAL	Vanadium	mg/kg	1	1	100%	--	--	101	101	101	--	--	101	Max Detect
METAL	Zinc	mg/kg	1	1	100%	--	--	65	65	65	--	--	65	Max Detect
RAD	Americium-241	pCi/g	6	5	83%	41	41	0.020	0.21	3.5	1.10E+06	10	0.21	Max Detect
RAD	Cesium-137	pCi/g	9	9	100%	--	--	0.010	529,000	58,780	2.43E+18	168,106	529,000	Max Detect
RAD	Cobalt-60	pCi/g	4	4	100%	--	--	0.010	0.070	0.043	2.2	0.072	0.070	Max Detect
RAD	Europium-155	pCi/g	3	3	100%	--	--	0.050	0.10	0.073	0.23	0.12	0.10	Max Detect
RAD	Neptunium-237	pCi/g	3	1	33%	0.010	0.010	0.020	0.020	0.010	4.0	0.025	0.020	Max Detect
RAD	Nickel-63	pCi/g	10	3	30%	0.41	2.3	2.1	2,110	212	19,716	599	2,110	Max Detect
RAD	Plutonium-238	pCi/g	4	1	25%	0.020	7.8	0.040	0.040	1.00	1.61E+16	3.3	0.040	Max Detect
RAD	Plutonium-239/240	pCi/g	7	5	71%	0.010	0.010	0.010	195	28	1.46E+10	82	195	Max Detect

Table C-6. Summary of Statistics for Deep Zone Soils from the 216-B-26 Trench. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Concentration	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
RAD	Potassium-40	pCi/g	11	11	100%	--	--	10	22	15	18	17	18	Log Normal
RAD	Radium-226	pCi/g	11	11	100%	--	--	0.28	0.94	0.56	0.78	0.70	0.78	Log Normal
RAD	Radium-228	pCi/g	9	8	89%	0.66	0.66	0.51	1.6	0.89	1.4	1.1	1.1	Normal
RAD	Technetium-99	pCi/g	9	5	56%	0.080	2.5	0.61	92	12	2,995	30	92	Max Detect
RAD	Thorium-228	pCi/g	11	11	100%	--	--	0.62	3.0	1.0	1.4	1.4	1.4	Log Normal
RAD	Thorium-230	pCi/g	11	7	64%	0.040	0.28	0.30	0.72	0.32	1.1	0.45	0.45	Normal
RAD	Thorium-232	pCi/g	11	11	100%	--	--	0.47	3.0	1.1	1.5	1.5	1.5	Log Normal
RAD	Tin-126	pCi/g	8	3	38%	0.11	0.37	0.13	0.18	0.14	0.21	0.17	0.17	Normal
RAD	Strontium-90	pCi/g	9	5	56%	0.070	0.12	0.34	974,000	108,223	1.06E+19	309,516	974,000	Max Detect
RAD	Tritium	pCi/g	7	6	86%	0.080	0.080	0.32	43	7.5	12,430	19	43	Max Detect
RAD	Uranium-233/234	pCi/g	12	11	92%	32	32	0.12	7.8	2.9	46	5.4	7.8	Max Detect
RAD	Uranium-235	pCi/g	8	8	100%	--	--	0.010	0.48	0.14	5.3	0.28	0.48	Max Detect
RAD	Uranium-238	pCi/g	12	11	92%	32	32	0.12	8.2	2.9	49	5.5	8.2	Max Detect
SVOC	Bis(2-ethylhexyl) adipate	mg/kg	1	1	100%	--	--	0.22	0.22	0.22	--	--	0.22	Max Detect
SVOC	Diethylphthalate	mg/kg	6	6	100%	--	--	0.32	0.62	0.45	0.59	0.55	0.59	Log Normal
SVOC	Heneicosane	mg/kg	1	1	100%	--	--	2.1	2.1	2.1	--	--	2.1	Max Detect
SVOC	Phosphine oxide triphenyl-	mg/kg	1	1	100%	--	--	0.37	0.37	0.37	--	--	0.37	Max Detect
TPH	Total petroleum hydrocarbons - motor oil (high boiling)	mg/kg	1	1	100%	--	--	32	32	32	--	--	32	Max Detect

95UCL = 95th upper confidence level.
CONV = conventional parameter.
EPC = exposure point concentration.
Max Detect = maximum detection.
RAD = radiological.
SVOC = semivolatile organic compound.
TPH = total petroleum hydrocarbon.

Table C-7. Summary of Statistics for Deep Zone Soils from the 216-B-46 Crib. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Detected Result	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
CONV	Free cyanide	mg/kg	1	1	100%	--	--	0.32	0.32	0.32	0		0.32	Max Detect
METAL	Aluminum	mg/kg	9	9	100%	--	--	3,220	4,720	3,890	4,219	4,187	4,187	Normal
METAL	Antimony	mg/kg	9	1	11%	4.0	8.9	5.7	5.7	3.0	4.0	3.8	4.0	Log Normal
METAL	Arsenic	mg/kg	9	9	100%	--	--	1.0	2.7	1.7	2.1	2.0	2.1	Log Normal
METAL	Barium	mg/kg	9	9	100%	--	--	42	71	60	68	66	66	Normal
METAL	Beryllium	mg/kg	9	8	89%	0.22	0.22	0.21	0.44	0.27	0.38	0.33	0.33	Normal
METAL	Cadmium	mg/kg	9	3	33%	0.59	1.3	0.71	1.5	0.65	1.1	0.91	1.1	Log Normal
METAL	Calcium	mg/kg	9	9	100%	--	--	5,070	7,750	6,102	6,628	6,604	6,628	Log Normal
METAL	Chromium	mg/kg	9	9	100%	--	--	4.0	8.5	5.9	6.9	6.7	6.9	Log Normal
METAL	Cobalt	mg/kg	9	7	78%	7.1	8.7	5.2	9.4	6.2	7.7	7.3	7.7	Log Normal
METAL	Copper	mg/kg	9	9	100%	--	--	7.0	18	11	13	13	13	Log Normal
METAL	Iron	mg/kg	9	9	100%	--	--	9,530	16,500	12,270	13,729	13,588	13,729	Log Normal
METAL	Lead	mg/kg	9	9	100%	--	--	2.5	5.7	3.9	4.7	4.5	4.7	Log Normal
METAL	Magnesium	mg/kg	9	9	100%	--	--	2,480	3,420	3,020	3,257	3,229	3,229	Normal
METAL	Manganese	mg/kg	9	9	100%	--	--	174	267	233	257	253	253	Normal
METAL	Mercury	mg/kg	9	3	33%	0.050	0.050	0.060	0.24	0.070	0.19	0.12	0.19	Log Normal
METAL	Nickel	mg/kg	9	9	100%	--	--	4.5	18	9.3	12	12	12	Log Normal
METAL	Potassium	mg/kg	9	9	100%	--	--	459	1,250	826	1,045	980	980	Normal
METAL	Sodium	mg/kg	9	7	78%	132	132	186	2,830	657	4,072	1,240	2,830	Max Detect
METAL	Thallium	mg/kg	9	1	11%	0.38	0.44	0.60	0.60	0.25	0.32	0.33	0.32	Log Normal
METAL	Uranium	mg/kg	10	6	60%	0.30	0.70	0.84	35	5.7	159	12	35	Max Detect
METAL	Vanadium	mg/kg	9	9	100%	--	--	16	30	22	26	25	26	Log Normal
METAL	Zinc	mg/kg	9	7	78%	20	22	21	39	24	35	29	29	Normal
RAD	Cesium-137	pCi/g	12	10	83%	0.030	0.030	0.061	276,000	35,749	8.96E+21	80,642	276,000	Max Detect
RAD	Cobalt-60	pCi/g	12	2	17%	0.010	3.0	0.14	0.46	0.21	4.4	0.43	0.46	Max Detect
RAD	Gross alpha	pCi/g	12	11	92%	3.0	3.0	4.7	320	45	217	94	217	Log Normal
RAD	Gross beta	pCi/g	12	9	75%	32	170	27	1.24E+06	156,582	1.09E+12	355,445	1.24E+06	Max Detect
RAD	Plutonium-238	pCi/g	12	4	33%	0.010	0.070	0.027	6.3	0.73	21	1.7	6.3	Max Detect
RAD	Plutonium-239	pCi/g	9	2	22%	0.010	0.020	0.010	0.93	0.11	0.97	0.30	0.93	Max Detect
RAD	Plutonium-239/240	pCi/g	3	3	100%	--	--	3.5	227	98	6.88E+20	293	227	Max Detect
RAD	Potassium-40	pCi/g	9	9	100%	--	--	9.9	15	13	14	14	14	Normal

Table C-7. Summary of Statistics for Deep Zone Soils from the 216-B-46 Crib. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Detected Result	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
RAD	Radium-226	pCi/g	9	8	89%	40	40	0.68	2.4	3.2	8.9	7.1	2.4	Max Detect
RAD	Strontium-90	pCi/g	12	11	92%	0.040	0.040	0.060	264,000	36,756	3.44E+20	81,633	264,000	Max Detect
RAD	Technetium-99	pCi/g	12	3	25%	0.80	70	90	120	28	5,438	52	120	Max Detect
RAD	Thorium-228	pCi/g	9	8	89%	3.0	3.0	0.0060	0.010	0.17	1.7	0.48	0.010	Max Detect
RAD	Tritium	pCi/g	3	3	100%	--	--	11	27	17	158	32	27	Max Detect
SVOA	Benzoic acid	mg/kg	7	1	14%	1.7	1.8	0.041	0.041	0.75	7.7	0.98	0.041	Max Detect
SVOA	Bis(2-ethylhexyl) phthalate	mg/kg	7	3	43%	0.34	0.35	0.042	0.099	0.13	0.27	0.17	0.099	Max Detect
SVOA	Di-n-butylphthalate	mg/kg	7	4	57%	0.34	0.35	0.051	0.096	0.12	0.20	0.16	0.096	Max Detect
VOA	Methylene chloride	mg/kg	7	1	14%	0.0060	0.013	0.0010	0.0010	0.0036	0.0069	0.0048	0.0010	Max Detect

95UCL = 95th upper confidence level.
CONV = conventional parameter.
EPC = exposure point concentration.
Max Detect = maximum detection.
RAD = radiological.
SVOA = semivolatile organic compound.
VOA = volatile organic compound.

Table C-8. Summary of Statistics for Deep Zone Soils from the 216-B-58 Trench. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Concentration	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
CONV	Ammonium ion	mg/kg	15	8	53%	0.25	0.26	0.29	6.8	0.95	2.5	1.8	2.5	Log Normal
CONV	Chloride	mg/kg	15	14	93%	2.6	2.6	3.0	36	8.1	13	12	13	Log Normal
CONV	Cyanide	mg/kg	15	2	13%	0.20	0.20	0.26	0.36	0.13	0.15	0.16	0.15	Log Normal
CONV	Fluoride	mg/kg	15	1	7%	1.0	1.2	2.7	2.7	0.71	0.85	0.97	0.85	Log Normal
CONV	Nitrate	mg/kg	15	15	100%	--	--	3.7	255	42	104	77	104	Log Normal
CONV	Nitrogen in nitrite and nitrate	mg/kg	15	15	100%	--	--	0.64	83	11	33	21	33	Log Normal
CONV	Oil and grease	mg/kg	14	1	7%	683	718	1,350	1,350	420	498	547	498	Log Normal
CONV	Phosphate	mg/kg	15	1	7%	2.4	2.7	4.5	4.5	1.5	1.8	1.9	1.8	Log Normal
CONV	Sulfate	mg/kg	15	13	87%	5.0	5.0	6.4	62	19	39	26	39	Log Normal
CONV	Sulfide	mg/kg	14	2	14%	20	30	26	33	14	17	17	17	Log Normal
METAL	Arsenic	mg/kg	15	15	100%	--	--	5.6	16	9.3	11	11	11	Log Normal
METAL	Barium	mg/kg	15	15	100%	--	--	53	150	77	87	87	87	Log Normal
METAL	Bismuth	mg/kg	15	1	7%	4.9	10	9.9	9.9	3.1	3.8	4.0	3.8	Log Normal
METAL	Chromium	mg/kg	15	11	73%	3.0	6.0	3.4	8.2	4.5	6.4	5.4	5.4	Normal
METAL	Copper	mg/kg	15	3	20%	4.9	10	5.1	12	3.7	4.8	4.9	4.8	Log Normal
METAL	Nickel	mg/kg	15	14	93%	10	10	5.2	11	8.5	9.6	9.3	9.3	Normal
METAL	Selenium	mg/kg	15	15	100%	--	--	3.9	13	6.3	7.4	7.4	7.4	Log Normal
PCB	Aroclor-1254	mg/kg	15	1	7%	0.049	0.058	0.93	0.93	0.086	0.097	0.19	0.097	Log Normal
RAD	Americium-241	pCi/g	4	4	100%	--	--	0.080	412	108	3.94E+42	347	412	Max Detect
RAD	Cesium-137	pCi/g	11	11	100%	--	--	0.010	14,600	1,337	9.52E+09	3,741	14,600	Max Detect
RAD	Cobalt-60	pCi/g	8	8	100%	--	--	0.010	1,700	216	5.82E+10	618	1,700	Max Detect
RAD	Europium-154	pCi/g	1	1	100%	--	--	8.1	8.1	8.1	--	--	8.1	Max Detect
RAD	Europium-155	pCi/g	5	3	60%	0.030	0.040	0.060	0.070	0.045	0.19	0.069	0.069	Normal
RAD	Neptunium-237	pCi/g	4	2	50%	0.010	0.010	0.010	0.030	0.013	0.56	0.027	0.030	Max Detect
RAD	Nickel-63	pCi/g	11	2	18%	0.12	2.1	36	165	19	1,046	46	165	Max Detect
RAD	Plutonium-238	pCi/g	14	5	36%	0.010	0.050	0.080	31	3.8	3,364	8.3	31	Max Detect
RAD	Plutonium-239/240	pCi/g	11	10	91%	0.010	0.010	0.030	310	54	1.25E+08	115	310	Max Detect
RAD	Potassium-40	pCi/g	13	13	100%	--	--	12	18	15	16	16	16	Normal
RAD	Radium-226	pCi/g	10	10	100%	--	--	0.33	0.89	0.55	0.64	0.63	0.64	Log Normal
RAD	Radium-228	pCi/g	13	12	92%	0.53	0.53	0.52	4.4	1.1	1.6	1.6	1.6	Log Normal
RAD	Thorium-228	pCi/g	15	15	100%	--	--	0.38	6.9	1.3	1.7	2.0	1.7	Log Normal

Table C-8. Summary of Statistics for Deep Zone Soils from the 216-B-58 Trench. (2 Pages)

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Minimum Nondetected Result	Maximum Nondetected Result	Minimum Detected Result	Maximum Detected Result	Average Concentration	95UCL Lognormal Result	95UCL Normal Result	EPC	EPC Basis
RAD	Thorium-230	pCi/g	15	12	80%	0.14	0.33	0.31	0.67	0.38	0.60	0.46	0.46	Normal
RAD	Thorium-232	pCi/g	15	13	87%	0.25	0.53	0.52	4.4	1.1	1.8	1.5	1.8	Log Normal
RAD	Strontium-90	pCi/g	9	7	78%	0.12	0.12	0.28	18,400	2,056	1.14E+11	5,856	18,400	Max Detect
RAD	Tritium	pCi/g	13	12	92%	0.040	0.040	0.91	798	147	305,689	258	798	Max Detect
RAD	Uranium-233/234	pCi/g	15	15	100%	--	--	0.10	0.74	0.20	0.25	0.27	0.25	Log Normal
RAD	Uranium-235	pCi/g	12	12	100%	--	--	0.010	0.13	0.025	0.039	0.042	0.039	Log Normal
RAD	Uranium-238	pCi/g	15	15	100%	--	--	0.090	0.58	0.19	0.23	0.24	0.23	Log Normal
SVOC	1 1'-Biphenyl 2 3' 4' 5 5'- pentachloro-	mg/kg	1	1	100%	--	--	1.2	1.2	1.2	--	--	1.2	Max Detect
SVOC	Diethylphthalate	mg/kg	15	11	73%	0.19	0.22	0.31	0.90	0.40	0.70	0.51	0.51	Normal
SVOC	Mesityl oxide	mg/kg	1	1	100%	--	--	0.80	0.80	0.80	--	--	0.80	Max Detect
SVOC	n-Hexatriacontane	mg/kg	1	1	100%	--	--	0.84	0.84	0.84	--	--	0.84	Max Detect
VOC	Acetone	mg/kg	15	1	7%	0.0020	0.010	0.052	0.052	0.0053	0.0075	0.011	0.0075	Log Normal
VOC	Methylene chloride	mg/kg	15	1	7%	0.0020	0.0050	0.010	0.010	0.0018	0.0024	0.0029	0.0024	Log Normal

95UCL = 95th upper confidence level.
CONV = conventional parameter.
EPC = exposure point concentration.
Max Detect = maximum detection.
RAD = radiological.
PCB = polychlorinated biphenyl.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

Table C-9. Comparison of Maximum Detected Values in Shallow Zone Soils from the 216-B-26 Trench to Background Concentrations.

Constituent Class	Constituent Name	Unit	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Aluminum	mg/kg	7,110	11,800	No
METAL	Calcium	mg/kg	8,980	17,200	No
METAL	Chromium	mg/kg	7.1	18.5	No
METAL	Copper	mg/kg	20	22	No
METAL	Hexavalent Chromium	mg/kg	0.61	NA	Yes
METAL	Lead	mg/kg	4.3	10.2	No
METAL	Magnesium	mg/kg	6,080	7,060	No
METAL	Manganese	mg/kg	641	512	Yes
METAL	Mercury	mg/kg	0.070	0.33	No
METAL	Nickel	mg/kg	11	19.1	No
METAL	Potassium	mg/kg	784	2150	No
METAL	Silver	mg/kg	0.24	0.73	No
METAL	Uranium	mg/kg	57	3.21	Yes
METAL	Vanadium	mg/kg	101	85.1	Yes
METAL	Zinc	mg/kg	65	67.8	No
RAD	Cesium-137	pCi/g	529,000	1.05	Yes
RAD	Nickel-63	pCi/g	2,110	NA	Yes
RAD	Plutonium-239/240	pCi/g	195	0.0248	Yes
RAD	Strontium-90	pCi/g	974,000	0.178	Yes

NA = not applicable.
RAD = radiological.

Table C-10. Comparison of Maximum Detected Values in Shallow Zone Soils from the 216-B-46 Crib to Background Concentrations.

Constituent Class	Constituent Name	Unit	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Aluminum	mg/kg	4,720	11,800	No
METAL	Antimony	mg/kg	5.7	5	Yes
METAL	Arsenic	mg/kg	2.7	6.47	No
METAL	Barium	mg/kg	71	132	No
METAL	Beryllium	mg/kg	0.44	1.51	No
METAL	Cadmium	mg/kg	1.5	0.81	Yes
METAL	Calcium	mg/kg	7,750	17,200	No
METAL	Chromium	mg/kg	6.7	18.5	No
METAL	Cobalt	mg/kg	8.2	15.7	No
METAL	Copper	mg/kg	12	22	No
METAL	Iron	mg/kg	14,000	32,600	No
METAL	Lead	mg/kg	5.7	10.2	No
METAL	Magnesium	mg/kg	3,400	7,060	No
METAL	Manganese	mg/kg	267	512	No
METAL	Mercury	mg/kg	0.060	0.33	No
METAL	Nickel	mg/kg	10	19.1	No
METAL	Potassium	mg/kg	1,250	2150	No
METAL	Sodium	mg/kg	263	690	No
METAL	Thallium	mg/kg	0.60	NA	Yes
METAL	Uranium	mg/kg	1.7	3.21	No
METAL	Vanadium	mg/kg	29	85.1	No
METAL	Zinc	mg/kg	31	67.8	No
RAD	Cesium-137	pCi/g	0.20	1.05	No
RAD	Potassium-40	pCi/g	14	16.6	No
RAD	Radium-226	pCi/g	0.95	0.815	Yes
RAD	Strontium-90	pCi/g	0.45	0.178	Yes
RAD	Thorium-228	pCi/g	0.010	NA	Yes

NA = not applicable.
RAD = radiological.

Table C-11. Comparison of Maximum Detected Values in Shallow Zone Soils from the 216-B-58 Trench to Background Concentrations.

Constituent Class	Constituent Name	Unit	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Arsenic	mg/kg	8.8	6.47	Yes
METAL	Barium	mg/kg	87	132	No
METAL	Chromium	mg/kg	4.8	18.5	No
METAL	Nickel	mg/kg	11	19.1	No
METAL	Selenium	mg/kg	4.7	0.78	Yes
RAD	Americium-241	pCi/g	0.080	NA	Yes
RAD	Cesium-137	pCi/g	14	1.05	Yes
RAD	Cobalt-60	pCi/g	1,700	0.00842	Yes
RAD	Neptunium-237	pCi/g	0.010	NA	Yes
RAD	Nickel-63	pCi/g	165	NA	Yes
RAD	Plutonium-238	pCi/g	20	0.00378	Yes
RAD	Plutonium-239/240	pCi/g	240	0.0248	Yes
RAD	Potassium-40	pCi/g	16	16.6	No
RAD	Radium-226	pCi/g	0.57	0.815	No
RAD	Radium-228	pCi/g	1.2	NA	Yes
RAD	Thorium-228	pCi/g	1.5	NA	Yes
RAD	Thorium-230	pCi/g	0.40	NA	Yes
RAD	Thorium-232	pCi/g	1.2	1.32	No
RAD	Strontium-90	pCi/g	0.41	0.178	Yes
RAD	Tritium	pCi/g	10	NA	Yes
RAD	Uranium-233/234	pCi/g	0.74	1.1	No
RAD	Uranium-235	pCi/g	0.13	0.109	Yes
RAD	Uranium-238	pCi/g	0.58	1.06	No

NA = not applicable.
RAD = radiological.

Table C-12. Comparison of Maximum Detected Values in Deep Zone Soils from the 216-B-26 Trench to Background Concentrations.

Constituent Class	Constituent Name	Unit	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Aluminum	mg/kg	7,110	11,800	No
METAL	Calcium	mg/kg	8,980	17,200	No
METAL	Chromium	mg/kg	8.9	18.5	No
METAL	Copper	mg/kg	20	22	No
METAL	Hexavalent chromium	mg/kg	0.61	NA	Yes
METAL	Lead	mg/kg	4.3	10.2	No
METAL	Magnesium	mg/kg	6,080	7,060	No
METAL	Manganese	mg/kg	641	512	Yes
METAL	Mercury	mg/kg	1.4	0.33	Yes
METAL	Nickel	mg/kg	18	19.1	No
METAL	Potassium	mg/kg	784	2,150	No
METAL	Silver	mg/kg	0.24	0.73	No
METAL	Uranium	mg/kg	57	3.21	Yes
METAL	Vanadium	mg/kg	101	85.1	Yes
METAL	Zinc	mg/kg	65	67.8	No
RAD	Americium-241	pCi/g	0.21	NA	Yes
RAD	Cesium-137	pCi/g	529,000	1.05	Yes
RAD	Cobalt-60	pCi/g	0.070	0.00842	Yes
RAD	Europium-155	pCi/g	0.10	0.0539	Yes
RAD	Neptunium-237	pCi/g	0.020	NA	Yes
RAD	Nickel-63	pCi/g	2,110	NA	Yes
RAD	Plutonium-238	pCi/g	0.040	0.00378	Yes
RAD	Plutonium-239/240	pCi/g	195	0.0248	Yes
RAD	Potassium-40	pCi/g	22	16.6	Yes
RAD	Radium-226	pCi/g	0.94	0.815	Yes
RAD	Radium-228	pCi/g	1.6	NA	Yes
RAD	Technetium-99	pCi/g	92	NA	Yes
RAD	Thorium-228	pCi/g	3.0	NA	Yes
RAD	Thorium-230	pCi/g	0.72	NA	Yes
RAD	Thorium-232	pCi/g	3.0	1.32	Yes
RAD	Tin-126	pCi/g	0.18	NA	Yes
RAD	Strontium-90	pCi/g	974,000	0.178	Yes
RAD	Tritium	pCi/g	43	NA	Yes
RAD	Uranium-233/234	pCi/g	7.8	1.1	Yes
RAD	Uranium-235	pCi/g	0.48	0.109	Yes
RAD	Uranium-238	pCi/g	8.2	1.06	Yes

NA = not applicable.
RAD = radiological.

Table C-13. Comparison of Maximum Detected Values in Deep Zone Soils from the 216-B-46 Crib to Background Concentrations – Human Health Risk Assessment.

Constituent Class	Constituent Name	Unit	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Aluminum	mg/kg	4,720	11,800	No
METAL	Antimony	mg/kg	5.7	5	Yes
METAL	Arsenic	mg/kg	2.7	6.47	No
METAL	Barium	mg/kg	71	132	No
METAL	Beryllium	mg/kg	0.44	1.51	No
METAL	Cadmium	mg/kg	1.5	0.81	Yes
METAL	Calcium	mg/kg	7,750	17,200	No
METAL	Chromium	mg/kg	8.5	18.5	No
METAL	Cobalt	mg/kg	9.4	15.7	No
METAL	Copper	mg/kg	18	22	No
METAL	Iron	mg/kg	16,500	32,600	No
METAL	Lead	mg/kg	5.7	10.2	No
METAL	Magnesium	mg/kg	3,420	7,060	No
METAL	Manganese	mg/kg	267	512	No
METAL	Mercury	mg/kg	0.24	0.33	No
METAL	Nickel	mg/kg	18	19.1	No
METAL	Potassium	mg/kg	1,250	2150	No
METAL	Sodium	mg/kg	2,830	690	Yes
METAL	Thallium	mg/kg	0.60	NA	Yes
METAL	Uranium	mg/kg	35	3.21	Yes
METAL	Vanadium	mg/kg	30	85.1	No
METAL	Zinc	mg/kg	39	67.8	No
RAD	Cesium-137	pCi/g	276,000	1.05	Yes
RAD	Cobalt-60	pCi/g	0.46	0.00842	Yes
RAD	Plutonium-238	pCi/g	6.3	0.00378	Yes
RAD	Plutonium-239	pCi/g	0.93	0.0248	Yes
RAD	Plutonium-239/240	pCi/g	227	0.0248	Yes
RAD	Potassium-40	pCi/g	15	16.6	No
RAD	Radium-226	pCi/g	2.4	0.815	Yes
RAD	Strontium-90	pCi/g	264,000	0.178	Yes
RAD	Technetium-99	pCi/g	120	NA	Yes
RAD	Thorium-228	pCi/g	0.010	NA	Yes
RAD	Tritium	pCi/g	27	NA	Yes

NA = not applicable.
RAD = radiological.

Table C-14. Comparison of Maximum Detected Values in Shallow Zone Soils from the 216-B-58 Trench to Background Concentrations.

Constituent Class	Constituent Name	Unit	Maximum Detected Result	90th Percentile Background Concentration	Does Maximum Concentration Exceed Background?
METAL	Arsenic	mg/kg	16	6.47	Yes
METAL	Barium	mg/kg	150	132	Yes
METAL	Bismuth	mg/kg	9.9	NA	Yes
METAL	Chromium	mg/kg	8.2	18.5	No
METAL	Copper	mg/kg	12	22	No
METAL	Nickel	mg/kg	11	19.1	No
METAL	Selenium	mg/kg	13	0.78	Yes
RAD	Americium-241	pCi/g	412	NA	Yes
RAD	Cesium-137	pCi/g	14,600	1.05	Yes
RAD	Cobalt-60	pCi/g	1,700	0.00842	Yes
RAD	Europium-154	pCi/g	8.1	0.0334	Yes
RAD	Europium-155	pCi/g	0.070	0.0539	Yes
RAD	Neptunium-237	pCi/g	0.030	NA	Yes
RAD	Nickel-63	pCi/g	165	NA	Yes
RAD	Plutonium-238	pCi/g	31	0.00378	Yes
RAD	Plutonium-239/240	pCi/g	310	0.0248	Yes
RAD	Potassium-40	pCi/g	18	16.6	Yes
RAD	Radium-226	pCi/g	0.89	0.815	Yes
RAD	Radium-228	pCi/g	4.4	NA	Yes
RAD	Thorium-228	pCi/g	6.9	NA	Yes
RAD	Thorium-230	pCi/g	0.67	NA	Yes
RAD	Thorium-232	pCi/g	4.4	1.32	Yes
RAD	Strontium-90	pCi/g	18,400	0.178	Yes
RAD	Tritium	pCi/g	798	NA	Yes
RAD	Uranium-233/234	pCi/g	0.74	1.1	No
RAD	Uranium-235	pCi/g	0.13	0.109	Yes
RAD	Uranium-238	pCi/g	0.58	1.06	No

NA = not applicable.
RAD = radiological.

Table C-15. Summary of Contaminants of Potential Concern for the 216-B-26 Trench, 216-B-46 Crib, and 216-B-58 Trench. (2 Pages)

Contaminant of Potential Concern	216-B-26 Trench		216-B-46 Crib		216-B-58 Trench	
	Direct	GWP	Direct	GWP	Direct	GWP
Cyanide		X		X		X
Chloride		X				X
Fluoride	X	X			X	X
Nitrate	X	X			X	X
Nitrite	X	X				
Nitrogen in Nitrate and Nitrite	X	X			X	X
Antimony			X	X		
Arsenic					X	X
Barium						X
Cadmium			X	X		
Hexavalent Chromium	X	X				
Manganese	X	X				
Mercury		X				
Selenium					X	X
Thallium			X	X		
Uranium	X	X		X		
Vanadium		X				
Aroclor-1254						X
Acetone					X	X
Benzoic Acid			X	X		
Bis(2-ethylhexyl)phthalate		X	X	X		
Di-n-butylphthalate			X	X		
Diethylphthalate		X			X	X
Methylene Chloride				X		X
Am-241		X			X	X
Cs-137	X	X		X	X	X
Co-60		X		X	X	X
Eu-154						X
Eu-155		X				X
H-3		X		X	X	X
Ni-63	X	X			X	X
Np-237		X			X	X
Pu-238		X		X	X	X
Pu-239				X		
Pu-239/240	X	X		X	X	X
Ra-226	X	X	X	X		X
Ra-228		X			X	X
Sn-126		X				X
Sr-90	X	X	X	X	X	X

Table C-15. Summary of Contaminants of Potential Concern for the 216-B-26 Trench, 216-B-46 Crib, and 216-B-58 Trench. (2 Pages)

Contaminant of Potential Concern	216-B-26 Trench		216-B-46 Crib		216-B-58 Trench	
	Direct	GWP	Direct	GWP	Direct	GWP
Tc-99		X		X		
Th-228		X	X	X	X	X
Th-230		X			X	X
Th-232		X				X
U-233/234		X				
U-235		X			X	X
U-238		X				

GWP = groundwater protection.

Table C-16. Summary of Exposure Assumptions for Method C Soil and Ambient Air Cleanup Levels.

Parameter	Symbol	Unit	Industrial Land Use (Method C)*
Target risk	TR	unitless	1.00E-05
Target hazard quotient	THQ	unitless	1
Oral reference dose	RfDo	mg/kg-day	Chemical specific
Cancer potency factor	CPF	kg-day/mg	Chemical specific
Unit conversion factor	UCF	µg/mg	1,000
Body weight			
Carcinogens	BW	kg	70
Noncarcinogens	BW	kg	70
Carcinogenic averaging time	ATC	yr	75
Noncarcinogenic averaging time	ATN	yr	20
Drinking water fraction	DWF	unitless	1
Exposure duration			
Carcinogens	ED	yr	30
Noncarcinogens	ED	yr	6
Drinking water ingestion rate			
Carcinogens	DWIR	L/day	2
Noncarcinogens	DWIR	L/day	2
Inhalation correction factor			
Volatile compound	INH	unitless	2
Nonvolatile compound	INH	unitless	1

*WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties," equations 745-1 and 745-2.

Table C-17. Summary of Exposure Assumptions for Method B Groundwater Cleanup Levels.

Parameter	Symbol	Unit	Unrestricted Land Use (Method B)*
Target risk	TR	unitless	1.00E-06
Target hazard quotient	THQ	unitless	1
Oral reference dose	RfDo	mg/kg-day	Chemical specific
Cancer potency factor	CPF	kg-day/mg	Chemical specific
Unit conversion factor	UCF	µg/mg	1000
Body weight			
Carcinogens	BW	kg	70
Noncarcinogens	BW	kg	16
Carcinogenic averaging time	ATC	yr	75
Noncarcinogenic averaging time	ATN	yr	6
Drinking water fraction	DWF	unitless	1
Exposure duration			
Carcinogens	ED	yr	30
Noncarcinogens	ED	yr	6
Drinking water ingestion rate			
Carcinogens	DWIR	L/day	2
Noncarcinogens	DWIR	L/day	1
Inhalation correction factor			
Volatile compound	INH	unitless	2
Nonvolatile compound	INH	unitless	1

*WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards," (equations 740-1 and 740-2).

Table C-18. Comparison of Shallow Zone Exposure Point Concentration from 216-B-26 Trench to Method C Direct-Contact Soil Cleanup Levels.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	Method C Soil CUL	Does EPC Exceed Method C CUL?
CONV	Fluoride	mg/kg	1	1	100%	0.45	210,000	No
CONV	Nitrate (as N)	mg/kg	1	1	100%	7.1	5.60E+06	No
CONV	Nitrite (as N)	mg/kg	1	1	100%	0.32	350,000	No
CONV	Nitrogen in nitrite and nitrate	mg/kg	1	1	100%	4.9	79,007	No
METAL	Hexavalent chromium	mg/kg	1	1	100%	0.61	10,500	No
METAL	Manganese	mg/kg	1	1	100%	641	490,000	No
METAL	Uranium	mg/kg	1	1	100%	57	10,500	No
METAL	Vanadium	mg/kg	1	1	100%	101	24,500	No

WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."

CUL = cleanup level.
CONV = conventional parameter.
EPC = exposure point concentration.

Table C-19. Comparison of Deep Zone Exposure Point Concentrations from 216-B-26 Trench to Method B Groundwater Protection Cleanup Levels.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	EPC	Method B GWP CUL	Does True Mean Exceed GWP Method B CUL?	Are any Sample Results >2X CUL?	Number of Samples >CUL
CONV	Chloride	mg/kg	12	10	83%	9.5	1,000	No	--	--
CONV	Cyanide	mg/kg	12	2	17%	0.45	0.8	No	--	--
CONV	Fluoride	mg/kg	12	1	8%	0.45	24.1	No	--	--
CONV	Nitrate	mg/kg	12	10	83%	4,090	40	Yes	Yes	3
CONV	Nitrite	mg/kg	12	1	8%	0.32	4	No	--	--
CONV	Nitrogen in nitrite and nitrate	mg/kg	12	10	83%	1,080	173	Yes	Yes	1
METAL	Hexavalent chromium	mg/kg	12	1	8%	0.19	18.4	No	--	--
METAL	Manganese	mg/kg	1	1	100%	641	512[a]	Yes	No	1
METAL	Mercury	mg/kg	12	4	33%	0.76	2.09	No	--	--
METAL	Uranium	mg/kg	12	4	33%	57	3.21[b]	Yes	Yes	8
METAL	Vanadium	mg/kg	1	1	100%	101	2,240	No	--	--
SVOC	Bis(2-ethylhexyl) adipate	mg/kg	1	1	100%	0.22	13.9	No	--	--
SVOC	Diethylphthalate	mg/kg	6	6	100%	0.59	72.2	No	--	--

[a]The WAC 173-340-747 CUL for manganese (65.3 mg/kg) is less than background; therefore, CUL is defaulted to background concentration of 512 mg/kg.
[b]The WAC 173-340-747 CUL for total uranium (1.32 mg/kg) is less than background; therefore, CUL is defaulted to background concentration of 3.21 mg/kg.

WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection."

CONV = conventional parameter.
CUL = cleanup level.
GWP = groundwater protection.
EPC = exposure point concentration.
SVOC = semivolatile organic compound.

Table C-20. Comparison of Shallow Zone Exposure Point Concentration from 216-B-46 Crib to Method C Direct-Contact Soil Cleanup Levels.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	EPC	Method C Soil CUL	Does EPC Exceed Method C CUL?
METAL	Antimony	mg/kg	6	1	17%	5.6	1,400	No
METAL	Cadmium	mg/kg	6	2	33%	1.5	3,500	No
METAL	Thallium	mg/kg	6	1	17%	0.45	280	No
SVOC	Benzoic acid	mg/kg	4	1	25%	0.041	14,000,000	No
SVOC	Bis(2-ethylhexyl) phthalate	mg/kg	4	2	50%	0.049	9,375	No
SVOC	Di-n-butylphthalate	mg/kg	4	2	50%	0.096	350,000	No

WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."

CUL = cleanup level.
EPC = exposure point concentration.
SVOC = semivolatile organic compound.

Table C-21. Summary of Statistics for Deep Zone Soils from 216-B-46 Crib.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	EPC	Method B GWP CUL	Does True Mean Exceed GWP Method B CUL?	Are any Sample Results >2X CUL?	Number of Samples >CUL
CONV	Free Cyanide	mg/kg	1	1	100%	0.32	0.8	No	--	--
METAL	Antimony	mg/kg	9	1	11%	4.0	5.4	No	--	--
METAL	Cadmium	mg/kg	9	3	33%	1.1	0.69	Yes	0	3
METAL	Thallium	mg/kg	9	1	11%	0.32	1.59	No	--	--
METAL	Uranium	mg/kg	10	6	60%	35	3.21*	Yes	2	4
SVOA	Benzoic acid	mg/kg	7	1	14%	0.041	25,700	No	--	--
SVOA	Bis(2-ethylhexyl) phthalate	mg/kg	7	3	43%	0.099	13.9	No	--	--
SVOA	Di-n-butylphthalate	mg/kg	7	4	57%	0.096	56.5	No	--	--
VOA	Methylene chloride	mg/kg	7	1	14%	0.0010	0.0254	No	--	--

*The WAC 173-340-747 CUL for total uranium (1.32 mg/kg) is less than background; therefore, CUL is defaulted to background concentration of 3.21 mg/kg.

WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection."

CONV = conventional parameter.
CUL = cleanup level.
EPC = exposure point concentration.
GWP = groundwater protection.
SVOA = semivolatile organic compound.
VOA = volatile organic compound.

Table C-22. Comparison of Shallow Zone Exposure Point Concentration from 216-B-58 Trench to Method C Direct-Contact Soil Cleanup Levels.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	Method C Soil CUL	Does EPC Exceed Method C CUL?
CONV	Fluoride	mg/kg	2	1	50%	2.7	210,000	No
CONV	Nitrate (as N)	mg/kg	2	2	100%	40	5.60E+06	No
CONV	Nitrogen in nitrite and nitrate	mg/kg	2	2	100%	12	79,007	No
METAL	Arsenic	mg/kg	2	2	100%	8.8	87.5	No
METAL	Selenium	mg/kg	2	2	100%	4.7	17,500	No
SVOC	Diethylphthalate	mg/kg	2	1	50%	0.36	2,800,000	No
VOC	Acetone	mg/kg	2	1	50%	0.052	3.15E+06	No

WAC 173-340-745, "Soil Cleanup Standards for Industrial Properties."

CONV = conventional parameter.
CUL = cleanup level.
EPC = exposure point concentration.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

Table C-23. Summary of Statistics for Deep Zone Soils from 216-B-58 Trench.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	EPC	Method B GWP CUL	Does True Mean Exceed GWP Method B CUL?	Are any Sample Results >2X CUL?	Number of Samples >CUL
CONV	Chloride	mg/kg	15	14	93%	13	1000	No	--	--
CONV	Cyanide	mg/kg	15	2	13%	0.15	0.8	No	--	--
CONV	Fluoride	mg/kg	15	1	7%	0.85	24.1	No	--	--
CONV	Nitrate	mg/kg	15	15	100%	104	40	Yes	2	2
CONV	Nitrogen in nitrite and nitrate	mg/kg	15	15	100%	33	173	No	--	--
METAL	Arsenic	mg/kg	15	15	100%	11	6.5*	Yes	2	13
METAL	Barium	mg/kg	15	15	100%	87	923	No	--	--
METAL	Selenium	mg/kg	15	15	100%	7.4	5.2	Yes	1	9
PCB	Aroclor-1254	mg/kg	15	1	7%	0.097	0.485	No	--	--
SVOC	Diethylphthalate	mg/kg	15	11	73%	0.51	72.2	No	--	--
VOC	Acetone	mg/kg	15	1	7%	0.0075	28.9	No	--	--
VOC	Methylene chloride	mg/kg	15	1	7%	0.0024	0.0254	No	--	--

*The WAC 173-340-747 CUL for arsenic (0.034 mg/kg) is less than background; therefore, CUL is defaulted to background concentration of 6.5 mg/kg.

WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection."

CONV = conventional parameter.
CUL = cleanup level.
EPC = exposure point concentration.
GWP = groundwater protection.
PCB = polychlorinated biphenyl.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

Table C-24. Comparison of Maximum Shallow Zone Soil Concentrations from 216-B-26 Trench to Method C Ambient Air Cleanup Levels.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	PEF or VF (m^3/kg)	1/PEF or 1/VF (kg/m^3)	Maximum Air Concentration (mg/m^3)	Method C Ambient Air CUL (mg/m^3)	Does Maximum Air Concentration Exceed Ambient Air Method C CUL?
METAL	Hexavalent chromium	mg/kg	1	1	100%	0.61	1.32E+09	7.58E-10	4.62E-10	2.98E-07	No
METAL	Manganese	mg/kg	1	1	100%	641	1.32E+09	7.58E-10	4.86E-07	4.90E-05	No
METAL	Uranium	mg/kg	1	1	100%	57	1.32E+09	7.58E-10	4.31E-08	--	--
METAL	Vanadium	mg/kg	1	1	100%	101	1.32E+09	7.58E-10	7.65E-08	--	--

WAC 173-340-750, "Cleanup Standards to Protect Air Quality."

CUL = cleanup level.
PEF = particulate emissions factor.
VF = volatilization factor.

Table C-25. Comparison of Maximum Shallow Zone Soil Concentrations from 216-B-46 Crib to Method C Ambient Air Cleanup Levels.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	PEF or VF (m^3/kg)	1/PEF or 1/VF (kg/m^3)	Maximum Air Concentration (mg/m^3)	Method C Ambient air CUL (mg/m^3)	Does Maximum Air Concentration Exceed Ambient Air Method C CUL?
METAL	Antimony	mg/kg	6	1	17%	5.7	1.32E+09	7.58E-10	4.32E-09	--	No
METAL	Cadmium	mg/kg	6	2	33%	1.5	1.32E+09	7.58E-10	1.14E-09	--	No
METAL	Thallium	mg/kg	6	1	17%	0.60	1.32E+09	7.58E-10	4.55E-10	--	No
SVOC	Benzoic acid	mg/kg	4	1	25%	0.041	1.32E+09	7.58E-10	3.11E-11	--	No
SVOC	Bis(2-ethylhexyl) phthalate	mg/kg	4	2	50%	0.049	1.32E+09	7.58E-10	3.71E-11	0.00625	No
SVOC	Di-n-butylphthalate	mg/kg	4	2	50%	0.096	1.32E+09	7.58E-10	7.27E-11	0.35	No

WAC 173-340-750, "Cleanup Standards to Protect Air Quality."

CUL = cleanup level.
PEF = particulate emissions factor.
SVOC = semivolatile organic compound.
VF = volatilization factor.

Table C-26. Summary of Statistics for Shallow Zone Soils from 216-B-58 Trench.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	PEF or VF (m^3/kg)	1/PEF or 1/VF (kg/m^3)	Maximum Air Concentration (mg/m^3)	Method C Ambient Air CUL (mg/m^3)	Does Maximum Air Concentration Exceed Ambient Air Method C CUL?
METAL	Arsenic	mg/kg	2	2	100%	8.8	1.32E+09	7.58E-10	6.67E-09	5.814E-06	No
METAL	Selenium	mg/kg	2	2	100%	4.7	1.32E+09	7.58E-10	3.56E-09	--	No
SVOC	Diethylphthalate	mg/kg	2	1	50%	0.36	1.32E+09	7.58E-10	2.73E-10	2.8	No
VOC	Acetone	mg/kg	2	1	50%	0.052	1.26E+04	7.97E-05	4.14E-06	0.35	No

WAC 173-340-750, "Cleanup Standards to Protect Air Quality."

CUL = cleanup level.
PEF = particulate emissions factor.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.
VF = volatilization factor.

Table C-27. Summary of RESRAD Input Parameters, Human Health Risk Assessment. (5 Pages)

Description	Parameter	200-TW-1/200-PW-5 Value	Rationale and Citation
Exposure pathways		External gamma: active Inhalation: active Plant ingestion: suppressed Meat ingestion: suppressed Milk ingestion: suppressed Aquatic foods: suppressed Drinking water: suppressed Soil ingestion: active Radon: suppressed	Based on 200-TW-1/200-TW-2 work plan conceptual exposure model (DOE/RL-2000-38) and refinement of the model as part of the RI report (DOE/RL-2002-42); for protection of groundwater evaluation, only the drinking water pathway is active.
R011 - CZ	Area of CZ (m^2)	529	Site-specific areas from WIDS.
	Thickness of CZ (baseline) (m)	4.6	Assumes that site is contaminated at 95% UCL from surface to 4.6 m bgs.
	Length parallel to aquifer flow (m)	13	Site-specific.
	Radiation dose limit (industrial scenario)	15 mrem/yr	Risk framework.
	Elapsed time since waste placement (yr)	0	Environmental samples were collected in 2001.
	Exposure-point concentrations (pCi/g)	Chemical-specific	
Exposure-point concentrations	Cover depth (no-cover) (m)	0	Assumes that site is contaminated at 95% UCL from surface to 4.6 m bgs.
R013 - Cover and CZ Hydrological Data	Cover depth (cover) (m)	Varies by exposure area	Represents actual conditions of cover based on RI results.
	Cover material density (baseline) (g/cm^3)	1.6	Site-specific.
	Cover material density (cover) (g/cm^3)	1.6	Site-specific.
	Cover erosion rate (m/yr)	0.001	RESRAD default.
	Density of CZ (g/cm^3)	1.6	Site-specific values based on RI results.
	CZ erosion rate (m/yr)	0.001	RESRAD default.
	CZ total porosity (unitless)	0.43	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	CZ field capacity (unitless)	0.09	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	CZ hydraulic conductivity (m/yr)	6570	WHC-SD-EN-SE-004.
	CZ parameter (unitless)	4.05	ANL/EAD-4, Table E:2; CCN 070578.

Table C-27. Summary of RESRAD Input Parameters, Human Health Risk Assessment. (5 Pages)

Description	Parameter	200-TW-1/200-PW-5 Value	Rationale and Citation
	Humidity in air (g/m^3)	8	RESRAD default.
	Evapotranspiration coefficient (unitless)	0.656	EPA/910/R-97/005; WDOH/320-015.
	Wind speed (m/s)	3.4	PNNL-12087.
	Precipitation (m/yr)	0.16	Based on 16 cm (6.3 in.) average annual rainfall (DOE/RL-92-19).
	Irrigation rate (m/yr)	0	Industrial exposure scenario.
	Irrigation mode (unitless)	Overhead	RESRAD default.
	Runoff coefficient (unitless)	0.2	RESRAD default.
	Watershed area for nearby stream or pond (m^2)	1.00E+06	RESRAD default.
	Accuracy for water/soil computations (unitless)	0.001	RESRAD default.
	Density of SZ (g/cm^3)	1.9	Site-specific value based on RI results and BHI-01177.
R014 - SZ Hydrological Data	SZ total porosity (unitless)	0.27	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	SZ effective porosity (unitless)	0.23	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	SZ field capacity (unitless)	0.04	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	SZ hydraulic conductivity (m/yr)	365,000	WHC-SD-EN-SE-004.
	SZ parameter (unitless)	4.05	ANL/EAD-4, Table E:2; CCN 070578.
	Water table drop rate (m/yr)	0.001	RESRAD default.
	Well pump intake depth below water table (m)	4.6	Typical RCRA well screen length.
	Nondispersion or mass-balance (unitless)	Nondispersion	RESRAD default.
	Well pumping rate (m^3/yr)	250	RESRAD default.
	Number of unsaturated strata (unitless)	1	Site-specific.
R015 - Uncontaminated and Unsaturated Strata Hydrological Data	Thickness - Strata 1 (m)	23.2	Site-specific values based on RI results and current water table elevation data.
	Soil density (g/cm^3)	1.9	Site-specific value based on RI results and BHI-01177.
	Total porosity (unitless)	0.27	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	Effective porosity (unitless)	0.23	Site-specific values based on physical property samples from RI and WHC-EP-0883.

Table C-27. Summary of RESRAD Input Parameters, Human Health Risk Assessment. (5 Pages)

Description	Parameter	200-TW-1/200-PW-5 Value	Rationale and Citation
	Field capacity (unitless)	0.04	Site-specific values based on physical property samples from RI and WHC-EP-0883.
	Soil-specific parameter (unitless)	4.05	ANL/EAD-4, Table E:2; CCN 070578.
	Hydraulic conductivity (m/yr)	700	WHC-SD-EN-SE-004.
R016 - Distribution Coefficients and Leach Rates for Individual Radionuclides	Distribution coefficients (K_d) for contaminated zone, uncontaminated zone, and SZ (cm^3/g)	Am-241: 300 Co-60: 1,200 Cs-137: 1,500 Eu-152/154/155: 300 Tritium (H-3): 0 Ni-63: 300 Np-237: 15 Ra-226: 20 Pu-239/240: 200 Th-228: 3 Sr-90: 20 U-235: 2	PNNL-11800.
	Saturated leach rate yr^{-1}	0	RESRAD default.
	Saturated solubility (unitless)	0	RESRAD default.
	Inhalation rate (m^3/yr)	7,300	WDOH/320-015.
R017 - Inhalation and External Gamma	Mass loading for inhalation (g/m^3)	0.0001	WDOH/320-015.
	Dilution length for airborne dust (m)	3	RESRAD default.
	Exposure duration (yr)	30	WAC 173-340
	Inhalation shielding factor (unitless)	0.4	RESRAD default.
	External gamma shielding factor (unitless)	0.8	WDOH/320-015.
	Indoor time fraction (industrial scenario) (unitless)	0.137	200 Area industrial scenario; onsite 2,000 h/yr (indoors 60%).
	Outdoor time fraction (industrial scenario) (unitless)	0.091	200 Area industrial scenario; onsite 2,000 h/yr (outdoors 40%).
	Shape factor (unitless)	1	RESRAD default.
	Fruits, vegetables, and grain consumption (kg/yr)	110	WDOH/320-015.
R018 - Ingestion Pathway Data, Dietary Parameters	Leafy vegetable consumption (kg/yr)	Not applicable	WDOH/320-015.
	Milk consumption (L/yr)	Not applicable	WDOH/320-015.
	Meat and poultry consumption (kg/yr)	Not applicable	WDOH/320-015.

Table C-27. Summary of RESRAD Input Parameters, Human Health Risk Assessment. (5 Pages)

Description	Parameter	200-TW-1/200-PW-5 Value	Rationale and Citation
	Fish consumption (kg/yr)	Not applicable	WDOH/320-015.
	Other seafood consumption (kg/yr)	Not applicable	WDOH/320-015.
	Soil Ingestion (g/yr)	36.5	WDOH/320-015.
	Drinking water intake (L/yr)	730	WDOH/320-015.
	Drinking water contamination fraction (unitless)	1	RESRAD default.
	Household water contamination fraction (unitless)	1	RESRAD default.
	Livestock water contamination fraction (unitless)	1	RESRAD default.
	Irrigation water contamination fraction (unitless)	0	RESRAD default.
	Aquatic food contamination fraction (unitless)	1	RESRAD default.
	Plant food contamination fraction (unitless)	-1	RESRAD default.
	Meat contamination fraction (unitless)	-1	RESRAD default.
	Milk contamination fraction (unitless)	-1	RESRAD default.
	Livestock fodder intake for meat (kg/day)	68	RESRAD default.
R019 - Ingestion Pathway Data, Nondietary	Livestock fodder intake for milk (kg/day)	55	RESRAD default.
	Livestock water intake for meat (L/day)	50	RESRAD default.
	Livestock water intake for milk (L/day)	160	RESRAD default.
	Livestock intake of soil (kg/day)	0.5	RESRAD default.
	Mass loading for foliar deposition (g/m^3)	0.0001	RESRAD default.
	Depth of soil mixing layer (m)	0.15	RESRAD default.
	Depth of roots (m)	3	RESRAD default.
	Groundwater fractional usage - drinking water (unitless)	1	RESRAD default.
	Groundwater fractional usage - household usage (unitless)	1	RESRAD default.
	Groundwater fractional usage - livestock water (unitless)	1	RESRAD default.
	Groundwater usage - irrigation (unitless)	0	RESRAD default.
R021 - Radon	—	Not used	—

Table C-27. Summary of RESRAD Input Parameters, Human Health Risk Assessment. (5 Pages)

Description	Parameter	200-TW-1/200-PW-5 Value	Rationale and Citation

ANL/EAD-4, *User's Manual for RESRAD, Version 6.*
BHI-01177, *Borehole Summary Report for the 216-B-2-2 Ditch.*
CCN 070578, "Estimation of the Soil-Specific Exponential Parameter(s)."
DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report.*
DOE/RL-2000-38, *200-TW-1 Scavenged Waste Group Operable Unit and 200-TW-2 Tank Waste Group Operable Unit RI/FS Work Plan.*
DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit).*
EPA/910/R-97/005, *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund.*
PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*
PNNL-12087, *Climatological Data Summary 1998 with Historical Data.*
Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.
WAC 173-340, "Model Toxics Control Act -- Cleanup."
Waste Information Data System, Hanford Site database.
WDOH/320-015, *Hanford Guidance for Radiological Cleanup.*
WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site.*
WHC-SD-EN-SE-004, *Site Characterization Report: Results of Detailed Evaluation of the Suitability of the Site Proposed for Disposal of 200 Areas Treated Effluent.*

CZ = contaminated zone.
K_d = distribution coefficient.
RCRA = *Resource Conservation and Recovery Act of 1976.*
RESRAD = RESidual RADioactivity.
RI = remedial investigation
SZ = saturated zone.
UCL = upper confidence limit.
WIDS = *Waste Information Data System.*

Table C-28. Native American Exposure Scenario (from Harris and Harper 1997).[a]

Exposure Route	Subsistence Intake	Exposure Frequency (d/yr)
Soil, ingestion	200 mg/day	180
Soil, dermal	1 mg/cm^2-d, 5,000 cm^2	180
Soil, inhalation (dust)	20 m^3/day	180
Soil, external	24 h/day	180, 12 h/day
Air, inhalation	20 m^3/day	365
Water, ingestion	3 L/day	365
Water, inhalation	15 m^3/day	365
Water, dermal	0.17 h/day	365
Water, external	2.6 h/day, swimming	70
Biota, fish	0 g/day[b]	365
Biota, meat (game)	250 g/day	365
Biota, fowl	44 g/day	365
Biota, other organs	54 g/day	365
Biota, breast milk	742 mL/day	365 for 1 to 2 yr
Biota, fruit and vegetation	8.2 g/day or 574 g/70 kg-day	365
Sweat lodge, inhalation, and dermal	1 h/day	365

[a]Harris, S. G., and B. L. Harper, 1997, "A Native American Exposure Scenario," *Risk Analysis*, Vol. 17, No. 6, Plenum Publishing Corporation, New York, New York.

[b]No contaminated fish consumption is assumed because the contaminants currently in the vadose zone have been shown through modeling and comparison to groundwater protection standards to not impact the groundwater. Therefore, no impacts to the river or the fish are expected from these contaminants.

Table C-29. Dose and Risk for the 216-B-26 Trench.

Time (years)	Total Dose (mrem/yr)	Total Risk	Primary Radionuclide	Percent of Total Dose	Primary Pathway
Industrial Scenario					
0	3.1E+05	1E+00	Cs-137	99	Ground
1	3.1E+05	1E+00	Cs-137	99	Ground
50	9.9E+04	1E+00	Cs-137	99	Ground
150	9.8E+03	1E-01	Cs-137	99	Ground
500	6.9E+00	5E-05	Pu-239 Cs-137	49 43	Ground
1,000	3.5E+00	9E-06	Pu-239	94	Ground
Native American Scenario					
0	4.0E+06	6E+01	Cs-137 Sr-90	37 63	Plant Ground
1	3.9E+06	6E+01	Cs-137 Sr-90	37 63	Plant Ground
50	1.2E+06	2E+01	Cs-137 Sr-90	38 62	Plant Ground
150	1.1E+05	2E+00	Cs-137 Sr-90	40 60	Plant Ground
500	9.6E+01	6E-04	Cs-137 Pu-239 Sr-90	15 70 16	Plant Soil Ground
1,000	6.5E+00	1E-04	Pu-239	100	Ground
Groundwater Protection Exposure Pathway					
0	0.0E+00	0.0E+00	--	--	--
1	0.0E+00	0.0E+00	--	--	--
50	0.0E+00	0.0E+00	--	--	--
68	360	1E-03	Tc-99	100	Drinking water
150	0.0E+00	0.0E+00	--	--	--
500	0.0E+00	0.0E+00	--	--	--
1,000	0.0E+00	0.0E+00	--	--	--

Table C-30. Dose and Risk for the 216-B-46 Crib.

Time (years)	Total Dose (mrem/yr)	Risk	Primary Radionuclide	Percent of Total Dose	Primary Pathway
Industrial Scenario					
0	1.89E+00	4E-05	Ra-226	99.9	Ground
1	1.89E+00	4E-05	Ra-226	99.9	Ground
50	1.85E+00	4E-05	Ra-226	100.0	Ground
150	1.72E+00	4E-05	Ra-226	100.0	Ground
500	1.33E+00	3E-05	Ra-226	100.0	Ground
1,000	9.24E-01	2E-05	Ra-226	100.0	Ground
Native American Scenario					
0	2.12E+01	4E-04	Ra-226 Sr-90	79 21	Ground Plant
1	2.13E+01	4E-04	Ra-226 Sr-90	80 20	Ground Plant
50	2.48E+01	4E-04	Ra-226	-- 95	Ground Plant
150	2.37E+01	4E-04	Ra-226	99 --	Ground Plant
500	1.84E+01	3E-04	Ra-226	-- 100	Ground Plant
1,000	1.27E+01	2E-04	Ra-226	-- 100.0	Ground Plant
Groundwater Protection Exposure Pathway					
0	0.00E+00	0E+00	--	--	--
1	0.00E+00	0E+00	--	--	--
50	3.19E-01	1E-04	Tc-99	100.0	Drinking water
150	5.80E-03	1E-07	Tc-99	100.0	Drinking water
500	9.25E-04	7E-09	U-234	100.0	Drinking water
1,000	4.51E-05	3E-10	U-234	98.5	Drinking water

Table C-31. Dose and Risk for the 216-B-58 Trench.

Time (years)	Total Dose (mrem/yr)	Risk	Primary Radionuclide	Percent of Total Dose	Primary Pathway
Industrial Scenario					
0	4.60E+03	3E-02	Co-60	100	Ground
1	4.00E+03	2E-02	Co-60	100	Ground
50	1.40E+01	9E-05	Co-60 Cs-137 Pu-239	45 19 34	Ground Soil
150	5.15E+00	2E-05	Pu-239	92	Soil Inhalation
500	4.73E+00	1E-05	Pu-239	98	Soil Inhalation
1,000	4.69E+00	1E-05	Pu-239	98	Soil Inhalation
Native American Scenario					
0	2.08E+04	3E-02	Co-60	99	Ground
1	1.82E+04	2E-02	Co-60	99	Ground
50	1.34E+02	1E-02	Pu-239 Co-60	65 21 --	Plant Soil Ground
150	9.11E+01	6E-03	Pu-239	96 --	Plant Soil
500	8.65E+01	5E-04	Pu-239	99 --	Plant Soil
1,000	8.39E+01	3E-05	Pu-239	99 --	Plant Soil
Groundwater Protection Exposure Pathway					
0	0.0E+00	0E+00	--	--	--
1	0.0E+00	0E+00	--	--	--
50	0.0E+00	0E+00	--	--	--
66	1.7E+00	9E-06	H-3	100	Drinking water
150	2.2E-09	<1E-10	H-3	100	Drinking water
500	0.0E+00	0E+00	--	--	--
1,000	0.0E+00	0E+00	--	--	--

Table C-32. Comparison of Shallow Zone Soils from 216-B-26 Trench to Ecological Risk-Based Concentrations.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	Ecological RBC	Does EPC Exceed Ecological RBC
METAL	Hexavalent chromium	mg/kg	1	1	100%	0.61	67	No
METAL	Manganese	mg/kg	1	1	100%	641	1,500	No
METAL	Uranium	mg/kg	1	1	100%	57	NA	NA
METAL	Vanadium	mg/kg	1	1	100%	101	NA	NA
RAD	Cesium-137	pCi/g	1	1	100%	529,000	20	Yes
RAD	Nickel-63	pCi/g	1	1	100%	2,110	2.20E+07	No
RAD	Plutonium-239/240	pCi/g	1	1	100%	195	6,000	No
RAD	Strontium-90	pCi/g	1	1	100%	974,000	20	Yes

EPC = exposure point concentration.
NA = indicates that there is no ecological RBC available.
RAD = radiological.
RBC = risk-based concentration.

Table C-33. Comparison of Shallow Zone Soils from 216-B-46 Crib to Ecological Risk-Based Concentrations.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	EPC	Ecological RBC	Does EPC Exceed Ecological RBC
METAL	Antimony	mg/kg	6	1	17%	5.6	NA	NA
METAL	Cadmium	mg/kg	6	2	33%	1.5	14	No
METAL	Thallium	mg/kg	6	1	17%	0.45	NA	NA
RAD	Radium-226	pCi/g	6	6	100%	0.95	3.0	No
RAD	Strontium-90	pCi/g	6	5	83%	0.45	20	No
RAD	Thorium-228	pCi/g	6	6	100%	0.0094	2,200	No
SVOC	Benzoic acid	mg/kg	4	1	25%	0.041	NA	NA
SVOC	Bis(2-ethylhexyl) phthalate	mg/kg	4	2	50%	0.049	NA	NA
SVOC	Di-n-butylphthalate	mg/kg	4	2	50%	0.096	NA	NA

EPC = exposure point concentration.
NA = indicates that there is no ecological RBC available.
RAD = radiological.
RBC = risk-based concentration.
SVOC = semivolatile organic compound.

Table C-34. Comparison of Shallow Zone Soils from 216-B-58 Trench to Ecological Risk-Based Concentrations.

Constituent Class	Constituent Name	Unit	Number of Samples	Number of Detections	Frequency of Detection	Maximum Detected Result	Ecological RBC	Does EPC Exceed Ecological RBC
METAL	Arsenic	mg/kg	2	2	100%	8.8	7.0	Yes
METAL	Selenium	mg/kg	2	2	100%	4.7	0.30	Yes
RAD	Americium-241	pCi/g	1	1	100%	0.080	4,000	No
RAD	Cesium-137	pCi/g	2	2	100%	14	20	No
RAD	Cobalt-60	pCi/g	1	1	100%	1,700	700	Yes
RAD	Neptunium-237	pCi/g	1	1	100%	0.010	1,900	No
RAD	Nickel-63	pCi/g	1	1	100%	165	2.20E+07	No
RAD	Plutonium-238	pCi/g	2	2	100%	20	5,400	No
RAD	Plutonium-239/240	pCi/g	2	2	100%	240	6,000	No
RAD	Radium-228	pCi/g	1	1	100%	1.2	40	No
RAD	Thorium-228	pCi/g	2	2	100%	1.5	2,200	No
RAD	Thorium-230	pCi/g	2	2	100%	0.40	NA	NA
RAD	Strontium-90	pCi/g	2	2	100%	0.41	20	No
RAD	Tritium	pCi/g	1	1	100%	10	5,400	No
RAD	Uranium-235	pCi/g	2	2	100%	0.13	3,000	No
SVOC	Diethylphthalate	mg/kg	2	1	50%	0.36	NA	NA
VOC	Acetone	mg/kg	2	1	50%	0.052	NA	NA

EPC = exposure point concentration.
NA = indicates that there is no ecological RBC available.
RAD = radiological.
RBC = risk-based concentration.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

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APPENDIX D

COST ESTIMATE BACKUP

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CONTENTS

FIGURE

TABLES

TERMS

ACP	asphalt concrete pavement
CDF	control density fill
CERCLA	*Comprehensive Environmental Response, Compensation and Liability Act of 1980*
ERDF	Environmental Restoration Disposal Facility
ET	evapotranspiration
FFS	focused feasibility study
FH	Fluor Hanford, Inc.
FP	fixed price
G&A	general and administrative
HSSA	*Hanford Site Stability Agreement*
MCACES	*Micro-Computer Aided Cost Engineering System* database
O&M	operations and maintenance
PRG	preliminary remediation goal
RCRA	*Resource Conservation and Recovery Act of 1976*
RCT	radiological control technician

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APPENDIX D

COST ESTIMATE BACKUP

D1.0 INTRODUCTION

Cost estimates for this focused feasibility study (FFS) have an accuracy of +50 percent, -30 percent, which is the accuracy specified in the EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*. The cost estimates provide a discriminator for deciding between similar protective and implementable alternatives for a specific waste site. Therefore, the costs are relational costs for the evaluation of the alternatives, not absolute costs. Cost estimates were made by waste site, with the exception of five groups that were developed based on logistics. Two of the five groups are representative sites. This FFS does not evaluate the economies associated with implementing multiple sites or groups with a common alternative or aggregated remediation. This will be considered in the future as part of long-range planning and through the post-record-of-decision activities such as remedial design. Potential areas of cost sharing to reduce overall remediation costs include the following:

- Remediating all waste sites with a common preferred alternative at the same time
- Sharing mobilization/demobilization costs
- Sharing surveillance and maintenance costs
- Sharing barrier performance monitoring costs.

D2.0 BASES FOR EVALUATING ALTERNATIVES

This chapter describes the general bases for the cost estimates for the remedial alternatives developed in Chapter 6.0 of this FFS. A summary of the BC Cribs and Trenches capital cost estimate breakdown is provided in Table D-1. Tables D-2a and D-2b **now numbered D-6 and D-6b** provide parameters for the various alternatives. Table D-3 summarizes the ongoing surveillance and maintenance costs **not true; not here**.

Present-net-worth costs were estimated using the real discount rate published in Appendix C of the Office of Management and Budget OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, which is effective through the end of January 2004. Programs with durations longer than 30 yr use the 30-yr interest rate of 3.2 percent. Present-net-worth costs are discussed for each alternative in the following sections. Capital costs extended over multiple years are not discounted.

Non-discounted costs were calculated because of recommendations presented in EPA/540/R-00/002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, OSWER 9355.0-75. Non-discounted constant dollar costs demonstrate the impact of a discount rate on the total present value cost. The non-discounted costs are presented for comparison purposes only.

D2.1 ALTERNATIVE 1 – NO ACTION

The no-action alternative represents a situation where no legal restrictions, access controls, or active remedial measures are applied to the waste site. Taking no action implies "walking away from the waste site" and allowing the waste to remain in its current configuration, affected only by natural processes. No maintenance or other activities would be instituted or continued. Chapter 6.0 of the FFS describes the no-action alternative in more detail.

Because the no-action alternative assumes that no further actions will be taken at a waste site, costs are assumed to be zero.

D2.2 ALTERNATIVE 2 – MAINTAIN EXISTING SOIL COVER, INSTITUTIONAL CONTROLS, AND MONITORED NATURAL ATTENUATION

The primary costs associated with this alternative are surveillance and cover maintenance and monitored natural attenuation costs. This alternative also includes the cost of maintaining the existing soil cover. The costs for these controls were estimated based on the area of the individual waste sites or groups.

The unit cost for surveillance and maintenance was assumed to be the same as the current unit cost for surveillance and maintenance activities conducted annually on the waste sites. The unit cost accounts for such activities as site radiation surveys and repair of the existing soil cover on the sites where it is present. Because the existing soil cover is maintained annually, costs for replacing all or large portions of the existing cover at specified intervals (i.e., every 20 yr) are considered unnecessary.

The costs associated with natural attenuation monitoring are divided into three components: radiological surveys of surface soils, spectral gamma logging of vadose zone boreholes, and groundwater monitoring. The costs to perform radiological surveys of surface soils at waste sites are assumed to be similar to those for current survey practices at the sites and are included in the surveillance and maintenance costs.

Vadose zone monitoring costs assume spectral gamma logging of one borehole per waste site to a 15 m (50 ft) depth once every 5 yr until the site meets all preliminary remediation goals (PRG). This monitoring is considered for sites with high concentrations of contaminants in the shallow zone or near the bottom of crib and trench structures. It also assumes that the service life of vadose zone boreholes is 30 yr. Costs are included for logging and periodic replacement of these boreholes until all PRGs are met for the site.

Groundwater-monitoring costs will be incurred for sites that have high concentrations of mobile contaminants deep within the vadose zone and/or where groundwater contamination is known to have occurred. For this cost estimate, the groundwater-monitoring costs will be included for the 22 sites within the BC Cribs and Trenches Area that pose a potential groundwater threat. The remaining sites (former 200-LW-1 trenches, 200-E-14 Siphon Tank, and 200-E-114 Transfer Line) will not incur groundwater-monitoring costs.

The present-net-worth costs for surveillance and maintenance and natural attenuation monitoring are added to the periodic costs to reach the total present-worth cost for this alternative. The real discount rate of 3.1 percent is used for discounting real (constant-dollar) flows for the duration until all PRGs are reached at each site. The non-discounted cost for the 150-yr project duration is presented for comparison purposes.

D2.3 ALTERNATIVE 3 – REMOVAL, TREATMENT, AND DISPOSAL (EXCAVATION)

Individual waste sites are excavated to remove contaminated soil and structures that are contaminated at levels exceeding PRGs. Because contamination has migrated to depths of 150 ft, or more, and the deep contamination from individual waste sites has merged, the excavation consumes considerable area. Downblending of highly contaminated soil to satisfy the Environmental Restoration Disposal Facility (ERDF) waste acceptance criteria is anticipated, when appropriate. Following verification that contamination has been sufficiently removed and transported to the ERDF, the excavation is backfilled.

Following completion of the excavation and backfilling activities, no further operations and maintenance activities would occur except for the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)-required 5-yr reviews to evaluate effectiveness of the remedial action. As described above, the present-net-worth costs include these periodic costs to reach the total present-worth cost for this alternative. The real discount rate of 3.1 percent is used for discounting real (constant-dollar) flows for the duration until all PRGs are reached at each site. The non-discounted cost for the 150-yr project duration is presented for comparison purposes.

D2.4 ALTERNATIVE 4 – CAPPING

Containment of the contamination by a suitable barrier, or cap, is the objective of this alternative. No contaminants are removed. Because of the presence of high levels of contamination at depths less than 15 ft, the cap must include intruder-deterrent features. Also, because of high levels of Tc-99 and nitrate contamination at depths of 100 ft and greater, the cap must provide groundwater protection. Thus, except when waste sites are known to possess only groundwater risks, the cost of capping is based on costs for the *Resource Conservation and Recovery Act of 1976* (RCRA) Modified RCRA Subtitle C Barrier directly over individual waste sites. The area between waste sites and the periphery of the waste site grouping is covered with a simple evapotranspiration (ET) barrier. Figure D-1 shows the entire cap.

Following completion of the capping activities, operations and maintenance activities would include cap maintenance, groundwater monitoring, and the CERCLA-required 5-yr reviews to evaluate effectiveness of the remedial action. As described above, the present-net-worth costs include these periodic costs to reach the total present-worth cost for this alternative. The real discount rate of 3.1 percent is used for discounting real (constant-dollar) flows for the duration until all PRGs are reached at each site. The non-discounted cost for the 150-yr project duration is presented for comparison purposes.

D2.5 ALTERNATIVE 5 – PARTIAL EXCAVATION WITH CAPPING

This alternative excavates the near-surface contamination to reduce, or eliminate, the human health and intruder risk and covers the residual contamination with a cap to protect groundwater. Excavation is limited to 15 ft for the trenches and 20 ft for the cribs. Following excavation, the hole is backfilled and a cap is constructed. The cap does not require intruder-deterrent features.

Following completion of the capping activities, operations and maintenance activities would include cap maintenance, groundwater monitoring, and the CERCLA-required 5-yr reviews to evaluate effectiveness of the remedial action. As described above, the present-net-worth costs include these periodic costs to reach the total present-worth cost for this alternative. The real discount rate of 3.1 percent is used for discounting real (constant-dollar) flows for the duration until all PRGs are reached at each site. The non-discounted cost for the 150-yr project duration is presented for comparison purposes.

D3.0 ASSUMPTIONS AND COSTING

Assumptions used for Alternatives 1, 2, 3, 4, and 5 are discussed in the following sections.

D3.1 GLOBAL ASSUMPTIONS

D3.1.1 Labor

- Fixed-price (FP) construction craft labor rates are those listed in Appendix A to the *Site Stabilization Agreement for All Construction Work for the U.S. Department of Energy at the Hanford Site*, 1984, as amended, commonly known as the Hanford Site Stabilization Agreement (HSSA). The HSSA rates include base wage, fringe benefits, and other compensation as negotiated between Fluor Hanford, Inc. (FH), and the Building and Construction Trades Department of the American Federation of Labor-Congress of Industrial Organizations (AFL-CIO). Other factors have been incorporated to cover the additional costs for Workman's Compensation, *Federal Insurance Contributions Act* (FICA, *The Social Security Act of 1935*), and state and Federal unemployment insurance to develop a fully burdened rate by craft. The labor rates used are for 2004.

- FH labor rates for management, engineering, safety oversight, and technical support are based on fiscal year 2004 labor rates.

D3.1.2 Direct-Cost Factors

- Sales tax has been applied to all materials and equipment purchases at 8.3 percent.
- A factor of 18.4 percent has been applied to FP direct craft labor for general conditions to allow for hauling men and materials, clean-up labor support, and quality control inspection.
- Construction consumables are estimated at 3.5 percent of FP direct-craft labor costs to allow for small tools, tape, plastics, gloves, etc.
- A general foreman factor of 3 percent has been applied to FP craft labor hours.

D3.1.3 Indirect-Cost Factors

- The FP contractor overhead, profit, bond, and insurance costs have been applied at 26.5 percent on FP labor, materials, and equipment.
- An FH general and administrative (G&A) factor of 15 percent has been applied to all FH labor, material, and equipment. The G&A also is applied to the FP contractor costs.

D3.1.4 General Assumptions

- Construction labor, material, and equipment units have been estimated based on standard commercial estimating resources and databases: R. S. Means (Means, 2004, *Site Work and Landscape Cost Data*, 23rd ed); Richardson's *Process Plant Construction Estimating Standards* (Richardson Engineering Services, Inc.); and the US Army Corps of Engineers' *Micro-Computer Aided Cost Engineering System* (MCACES) database. The units may have been factored or adjusted by the estimator as appropriate to reflect influences by contract, work site, or other identified project or special conditions.
- Quotes from local commercial sources have been used for materials that need to be acquired for the construction of barriers or temporary improvements.
- There are 21 working days in a month.
- Work stoppages or shutdowns caused by inclement weather are not factored into the estimates or planning schedules for this study.
- Work delays or stoppages caused by waiting for lab results or approval for backfilling waste site excavations are not factored into the estimates or planning schedules for this study.

D3.2 ALTERNATIVE 2 – MAINTAIN EXISTING SOIL COVER, INSTITUTIONAL CONTROLS, AND MONITORED NATURAL ATTENUATION

D3.2.1 General Assumptions

The general assumptions for Alternative 2 are as follows.

- Fencing and monuments/signs for institutional controls and fencing maintenance are considered institutional costs and are not considered in this cost estimate.
- Periodic groundwater-monitoring costs for the BC Cribs and Trenches Area are included as described in Section D3.~~7~~2.2, seventh bullet,, Long-Term Groundwater Monitoring.
- Surface soil is not affected. Therefore, Level A, B, or C personal protective equipment is not needed for this alternative.

D3.2.2 General Activities

Alternative 2 consists of five general activities: institutional controls implementation, site inspection and surveillance, existing cover maintenance, natural attenuation monitoring, and site reviews.

- Implementation of Institutional Controls: Preparing and implementing institutional controls is a capital cost and includes office or administrative costs to implement deed restrictions, land-use restrictions, and groundwater-use restriction. Costs presented in the cost estimates are based on the following.
    - Time to produce institutional controls = 200 hours (assumption)
    - Labor rate = \$56/h (assumption).
- **Site Inspection and Surveillance:** The costs associated with site inspection and surveillance are operations and maintenance (O&M) costs. These costs will be incurred annually as long as the alternative is being used. The activities included under site inspection and surveillance are assumed to be the same as the activities currently being performed. These activities include site radiation surveys of surface soil and physical site inspection. Activities to control deeply burrowing animals and deep-rooted plants by using herbicide or by physical removal may be required, but costs for such activities are not included.

  For costing purposes, sites of 50,000 ft^2 or smaller are assumed to require a team of two inspectors and two 8-h days (16 crew hours) to perform the activities associated with site inspection and surveillance. An additional 16 crew hours will be needed for site inspection and surveillance for every additional 50,000 ft^2 of site area. The cost of site inspection and surveillance can be figured as follows:

- Area of representative site = 61,152 ft^2 (FFS description)
- Time to complete inspections = 32 h (16 h for every 50,000 ft^2)
- Hourly rate for team = $112/h
- Radiation surveys of surface soil = $13,000/event ($1,000 for every 5,000 ft^2).

- **Existing Cover Maintenance:** The cost associated with existing cover maintenance is an O&M cost. This cost will be incurred and the maintenance is performed annually as long as the alternative is being used. Cover maintenance is assumed to include replacing cover soils over 10 percent of the area to a depth of 2 ft on an annual basis. The soil used to repair the existing cover is a silt loam and pea gravel mixture. The pea gravel is used to make the soil resistant to wind erosion.

  For costing purposes, it is assumed that the silt loam/pea gravel have been blended and stockpiled at Area C by a fixed price contractor. This work occurs prior to when the mixture is needed for maintenance. The silt/pea gravel mixture has a unit price of $8.95/CY based on recent construction estimates.

  The silt/pea gravel is loaded into trucks at the stockpile using a front-end loader and operator. Four 10-12CY dump trucks with drivers haul to the wastes site. The loading and transport rate is 130 CY/Hr.

  Once the material is at the site, it is assumed that the silt/pea gravel will be placed on site in a loose lift. Spreading and re contouring will be performed by a low ground pressure dozer. Dust control at the site will be by a 3000gal water truck. Once the silt loam and pea gravel are in place, these areas will need to be vegetated.

  Fluor Hanford crews will load, haul, place, and re vegetate the site. It is assumed that Fluor Hanford will have a site engineer on site during cover maintenance activities to provide oversight.

- **Monitoring for Natural Attenuation:** The costs associated with natural attenuation monitoring are O&M costs. These costs will be incurred annually as long as the alternative is being used. The cost for natural attenuation monitoring includes spectral gamma logging of vadose zone boreholes.

Vadose zone monitoring costs assume spectral gamma logging of one borehole per waste site to a depth of 50 ft once every 5 yr. The service life of a vadose zone borehole is assumed to be 30 yr. Therefore, every 30 yr a replacement borehole will be drilled. Costs are based on the following:

- Unit cost for vadose zone monitoring = \$75/ft of borehole
- Length of borehole drilling = 50 ft
- Cost of vadose zone monitoring = \$75/ft x 50 ft = \$3,750
- Installation cost of borehole = \$45/linear ft
- Length of borehole installation = 50 ft
- Oversight = 1 day = 8 h

Other costs associated with installing replacement boreholes are included on the cost estimate sheets. These items include, but are not limited to, mobilization of a drill rig, decontamination of a drill rig, and handling of investigation-derived waste (IDW).

- **Site Reviews:** The cost associated with site reviews is an O&M cost. This cost will be incurred every 5 yr as long as the alternative is being used. Site reviews will be conducted to assess site conditions and to evaluate the selected alternative and determine whether additional steps toward remediation are required.

- **Decontamination Pad:** A decontamination pad will be constructed to clean the dynamic compaction equipment. It is assumed that the dynamic compaction equipment can be decontaminated for reuse and can be decontaminated in 1 day. The decontamination pad will be of a sufficient length and width to accommodate all proposed traffic to and from the site. The decontamination pad will consist of timber grates, plastic sheeting (60 mil LLDPE), PVC pipe, and a sump with a pump and hoses. Based on the Alternative 3 assumption for decontamination pad water use (1,000 gal/mo), 50 gal of water are required for 1 day of decontamination activity. Therefore, it is assumed that a temporary water source can be obtained for decontamination activities and large storage tanks will not be required. It also is assumed that the sump can adequately store the rinse water before using it for dust suppression on contaminated sites. Decontamination pad components are as follows:

Pad area	= 20 ft x 30 ft
	= 600 ft^2
Timber grates (2 in. x 4 in.)	= (2 x 5 x 30 ft) + (2 x 17 x 3 ft)
	= 402 linear feet
	= 0.402 m board ft

Plastic sheeting = (20 ft x 30 ft) + (2 x 8 ft overlap) + 10%
= 1,188 ft^2

3-in. PVC pipe = 5 linear ft.

All equipment rented for the decontamination pad will be rented for the duration of the remedial action activities, in the event that the decontamination pad is needed. It is assumed that equipment can be decontaminated for reuse.

The decontamination pad will be staffed for 1 day to decontaminate equipment. The decontamination crew will consist of four laborers. This crew will construct the decontamination pad, provide decontamination services, and remove the decontamination pad during demobilization activities (labor provided under miscellaneous costs).

- **Long-Term Groundwater-Monitoring:** For the BC Cribs and Trenches Area, each alternative that includes annual inspections and maintenance costs (Alternatives 2, 4, and 5) will include a cost for periodic groundwater monitoring that will be applied to the overall alternative cost. The cost associated with periodic groundwater monitoring is distributed equally over each site within the BC Cribs and Trenches Closure Zone. The following is a description of the periodic groundwater costs.

  The groundwater-monitoring program to be performed for the BC Cribs and Trenches Closure Zone will include the installation, maintenance, sampling, and replacement of three monitoring wells. The present-worth cost for the groundwater-monitoring program will be divided equally among the sites within the BC Cribs and Trenches Closure Zone. The BC Cribs and Trenches Closure Zone contains 26 sites that include all of the sites located in the south end of the 200 East Area except for the 200-E-14 Siphon Tank and the 200-E-114 Transfer Line.

  Based on historical information from similar Hanford Site planning, the cost to install a compliant monitoring well is approximately $180,000 per well. It is assumed that this cost includes all required labor and material.

  Cost to install wells (3 wells) = $180,000/well x 3 wells
  = $540,000

  Maintenance will need to be performed on each of the wells every 6 yr over the 150-yr active monitoring period. In addition, each of the wells will need to be replaced once every 30 yr.

  Maintenance costs (3 wells) = $5,000/well x 3 wells
  = $15,000 every 6 yr

  Replacement costs (3 wells) = $180,000/well x 3 wells
  = $540,000 every 30 yr

During each sampling event, three groundwater samples will be collected for analysis. The analyses and cost per analysis are listed below.

Tc-99	= $234/sample x 3 samples/event	= $702/event
Total uranium	= $73/sample x 3 samples/event	= $219/event
Nitrate	= $270/sample x 3 samples/event	= $810/event
Cs-137	= $180/sample x 3 samples/event	= $540/event
Sr-90 as total radiostrontium	= $353/sample x 3 samples/event	= $1,059/event
Isotopic plutonium	= $364/sample x 3 samples/event	= $1,092/event
Total analytical cost per sampling event		= $4,422

The labor cost of doing all the paper work, labeling, monitoring, and delivery to the laboratory is approximately $300 per well sampled.

Total labor cost	= $300/well x 3 wells
	= $900/sampling event

Total cost to collect and analyze samples per sampling event = $5,322

Sampling events will occur at the following frequencies:

Year 1	Quarterly (4 sampling events)
Year 2	Semiannually (2 sampling events)
Year 3 through 5	Annually (3 sampling events)
Year 6 through 10	Every 2 yr (3 sampling events)
Years 11 through 50	Every 5 yr (8 sampling events)
Years 51 through 150	Every 10 yr (10 sampling events).

The present-worth cost to conduct a periodic groundwater-monitoring program for each Closure Zone for 150 yr was calculated.

Present-worth cost for long-term groundwater program = $1,126,800.

The present-worth cost for long-term groundwater monitoring will be divided by the total number of sites in the BC Cribs and Trenches Closure Zone and added to the calculated and ratio costs. The total number of sites in the BC Cribs and Trenches Closure Zone is 26. Therefore, the groundwater-monitoring cost per site is $43,340.

Alternative 2 Activity Frequency				
Item	Alternatives 2			
	Annually	per 3 Years	per 5 Years	per 30 Years
Institutional Controls	Y			
Perform Existing Barrier Cover Inspection	Y			
Conduct Radiation Survey of Surface Soil			Y	
Maintain Existing Barrier Cover	Y			
Conduct Vadose Zone Monitoring			Y	
Prepare and Issue Sampling Reports			Y	
Conduct Site Reviews			Y	
Construct Decontamination Pad		Y		
Perform Ground Water Monitoring			Y	

D3.3 ALTERNATIVE 3 – REMOVAL, TREATMENT, AND DISPOSAL

Trenches and cribs are excavated to the required depth, and contaminated material is removed to the ERDF for disposal. The sites then are remediated. Excavation depth and mixing requirements are different for each group of trenches and cribs.

D3.3.1 General Assumptions

The general assumptions for Alternative 3 are as follows.

- The field work such as mobilization/demobilization, excavation, backfill, revegetation, and some for the post-construction work will be contracted to an FP contractor. The project management, radiological control technician (RCT) support, sampling, and safety oversight will be performed by FH. The waste disposal work involved with hauling from the site to the ERDF and the ERDF dumping cost/fees will be performed by the Environmental Restoration Contractor responsible for the ERDF.

- Mobilization and startup include site training; mobilization of equipment and personnel; installation of temporary construction fences; construction of staging/container storage areas and access roads; setting up office, change, and storage trailers with utilities, truck scales, temporary survey buildings, and decontamination areas.

- The deep excavation sites will have contaminated soil removed to a depth of 150 to 220 ft, depending on the site requirements. Side slopes will be terraced using 1:1.5 slope for each 25 ft of depth with a 10-ft-wide level terrace. This will be repeated for the full depth of the excavation. At the bottom of the excavation will be a 50-ft work zone on each side of the contaminated waste. Access to the bottom of the excavation site will be by 24-ft-wide haul road with a maximum grade of 10 percent.

- The shallow excavation sites will have contaminated waste removed to a depth of 30 ft. The sides of the excavation will be sloped at 1:1.5 to the bottom of the excavation. During the removal process, heavy equipment will be kept out of the excavation site.

- For deep excavation sites, overburden and uncontaminated soil will be removed and stockpiled near by. The rate of removal will vary and will be dependant on the volume of contaminated soil removed from the site. The top of the overburden excavation zone will be kept reasonably close to the top of the contaminated waste removal zone. More than one overburden removal crew may be required to keep pace with the contamination excavation. The excavation equipment used per crew is three 300 to 400-hp bulldozers, six 32 to 44-yd^3 self-propelled scrapers, one motor grader, and one 6,000-gal water tanker. Labor per crew is eleven operators and one laborer. The production rate for one crew to remove overburden is 1,740 yd^3/h.

- For shallow excavation sites of relatively small area, overburden will be removed with a 2 to 3-yd^3 excavator and two haul trucks. The soil will be stockpiled near the waste site. A highway truck with water tank trailer is used to control dust during this activity. The production rate for one crew is 127 yd^3/h.

- Contaminated waste that does not require mixing will be excavated using a 2 to 3-yd^3 hydraulic crawler excavator. The contaminated soil will be placed directly into lined ERDF containers and hauled from the excavation site. A highway truck with water tank trailer is used to control dust during this activity. Depending on the volume of waste to move, one to four crews can be working at a site. Crew labor is made up of one operator, one laborer, and one truck driver. The production rate for one crew is 55 yd^3/h. An FH RCT supports the work at 1.5 h per excavation crew hour.

- Contaminated waste requiring mixing at a ratio of 7 parts "near-clean" soil to 1 part contaminated soil will use the following process.

  - Starting at one of the planned trench excavating sites, one 2 to 3-yd^3 excavator excavates the overburden from a 20 to 30-ft length of trench. The overburden is stacked on one side of the trench within easy reach of the excavator (A).

  - When the overburden excavation gets within 1 ft of the layer to be removed, a second long-reach excavator (B) with a 1 to 1.5-yd^3 bucket is brought in to mix the waste to the required ratio and direct-load the haul trucks with ERDF containers.

  - Excavator A continues to strip the trench of overburden and place the soil in the mixing zone. The excavator also can move soil from the initial stockpile into the mixing zone.

  - Excavator B stays on one side of the trench, with haul trucks operating on the same side.

- This process continues, moving down the length of the trench.
- A water truck is used to control dust at the excavation site.
- An FH RCT supports the work at 1.5 h per excavation crew hour.
- The production rate for one crew is 13 yd^3/h. Most sites use three crews for this type of excavation.

- Air sampling will be performed during the excavation of contaminated soil. A minimum of two samples will be taken per day. The planning cost is $520 per sample. The sampling crew is made up of one sampler and one RCT.
- Soil samples will be taken of the overburden from ERDF containers and for verification of completion of the excavation. The soil-sampling cost was developed as follows.
  - Noncontaminated-soil sampling:
    - A maximum of 6 samples or 1 sample per yd^3, whichever is less.
    - The number of quality assurance samples required is 1
    - The planning cost is $1,262 per sample
    - The soil being sampled is the overburden that is uncontaminated and will not be removed from the site.
  - Sampling required for waste going to the ERDF:
    - One sample is required for every 70 containers
    - There will be a minimum of 6 samples per site
    - The number of quality assurance samples required is a minimum of 1 or 5 percent of the total of ERDF samples, whichever is greater
    - The planning cost per sample is $452/sample.
  - Preverification-process sampling:
    - One sample will be required per 2,500 m^2 (50 x 50 m or 26,899 ft^2)
    - There will be a minimum of 6 samples per site
    - The number of quality assurance samples required is a minimum of 2 or 5 percent of total the samples, which ever is greater
    - The planning cost is $2,227 per sample
    - These samples are the preliminary samples needed to determine if all of the required waste has been removed from a site being excavated
    - This process is expected to happen twice during the excavation process
    - If the samples show that the site has met the requirement, then the verification process will start.
  - Verification-process sampling:
    - One sample will be required per 625 m^2 (25 x 25 m or 6,724 ft^2)
    - There will be a minimum of 6 samples per site

    - The number of quality assurance samples required is a minimum of 2 or 5 percent of total of the samples, whichever is greater
    - The planning cost is $7,856 per sample for onsite laboratory analysis and $1,458 per sample for offsite laboratory analysis and shipping (based on 6 samples being processed at one time), for a total of $9,314 per sample
    - These samples are the final samples needed to determine if all of the required waste has been removed from a site being excavated
    - This process happens once during the excavation process.
  - Sampling crews:
    - Verification sampling – 1 h for each sample taken by a crew, made up of one FH RCT and one sampler technician
    - Other sampling (air, ERDF, noncontaminated) – 1 h for each sample taken by a crew, made up of one FH RCT and one sampler technician.

- The ERDF container handling and loading process begins with a site haul truck picking up an empty container at the staging area. The container is moved to a preparation area, where laborers install a bed liner and it is inspected by a half-time RCT. The haul truck and container are delivered to the loading area. After the container has been loaded, the liner is sealed and the container is secured by laborers. The container is moved to the survey building, where a team of three RCTs inspects and surveys the container and truck for contamination. From there, the haul truck and container are weighed on a platform scale and then driven to the storage area. The container is unloaded from the truck at the storage area. Three trucks are required to support each contaminated-excavation crew.

- The ERDF disposal fee and transportation and handling costs are estimated at $980 per container. An Environmental Restoration Contractor driver and truck/trailer will move a loaded container to the ERDF and then will take an empty container back to the staging area. The estimated costs include the rental of the containers used. For planning purposes, the capacity of an ERDF container is 11 bank yd^3 or 12.7 loose yd^3 of contaminated waste.

- Backfilling the deep-excavation site is performed by three different operations. The crews and the equipment used for the backfilling the deep excavation sites require larger and more pieces of construction equipment because of the volume of backfill material and the larger size of the work areas.

  - The moving of the stockpiled overburden back to the excavation site will require one or more crews, depending on the volume to be moved. The equipment used by a crew is two 300 to 400-hp bulldozers and six 32 to 44-yd^3 self-propelled scrapers. The labor required is eight operators. The production rate for one crew is 1,740 yd^3/h.

  - The moving of borrow material to the excavation site typically is performed by two crews hauling from an on-site pit source. The equipment used by one crew is one 7-yd^3 loader, a 300 hp bulldozer, nine 20-yd^3 highway truck/trailers, and one water truck. The labor required is 2 operators, 10 truck drivers, and one laborer. The production rate for one crew is 420 yd^3/h.

- Spreading and compaction of the backfill at the site is performed by one to two crews, depending on the volume of the backfill. The equipment used per crew is two 300-hp bulldozers, one motor grader, and two 6,000-gal water tankers. The labor is made up of five operators and one laborer. The production rate for one crew is 1,740 yd^3/h.

- Backfill for shallow sites is performed by three different operations.
  - The moving of the stockpiled overburden back to the excavation site will require one crew. The equipment used by a crew is one 4 to 5-yd^3 loader and two haul trucks. The labor required is one operator and two truck drivers. The production rate for one crew is 185 yd^3/h.
  - The moving of borrow material to the excavation site typically is performed by one crew hauling from an on-site pit source. The equipment used by a crew is one 4 to 5-yd^3 loader, six 20-yd^3 highway truck/trailers, and one water truck. The labor required is one operator and seven truck drivers. The production rate for one crew is 185 yd^3/h.
  - Spreading and compaction of the backfill at the site is performed by one crew. The equipment used per crew is one 300-hp bulldozer and one 6,000-gal water truck/trailer. Labor is made up of one operator, one truck driver, and one laborer. The production rate for one crew is 185 yd^3/h.

- Revegetation of the waste site includes planting native dry-land grass using tractors with seed drills and hand broadcasting, hand-planting sagebrush seedlings, and irrigation four times in the spring or early summer. All disturbed areas such as the waste site, stockpile, staging areas, and access roads are to be replanted.

- The FH project management team is made up of a part-time project manager with a full-time field supervisor and part-time engineering support. The Quality Assurance, Radiological Control, and Safety organizations also provide oversight, along with other support for contract management and project controls. The duration of this work is based on total project duration.

- Demobilization includes demobilization of equipment and personnel, removing temporary construction fences, staging/container storage areas, access roads, office/change/storage trailers, truck scales, temporary survey buildings, and decontamination areas.

D3.3.2 Site 216-B-23 to -28 and 216-B-52 Trenches

This group of trenches will be removed as one large deep excavation; therefore, these trenches are handled as one estimate. The trenches covered by this estimate are the 216-B-23, 216-B-24, 216-B-25, 216-B-26, 216-B-27, 216-B-28, and 216-B-52 Trenches.

The site work is estimated to take 1,615 days or 77 months. The remediation time is based on the following critical path items:

- Mobilization: 15 days
- Contaminated Waste Excavation: 1,288 days; includes both 7:1 mixing excavation and excavation without mixing. The excavation of the overburden occurs at the same time and requires less duration than excavation of the contaminated waste. Other items of work that occur during this time are hauling the containers to the survey area, storing and then moving them to the ERDF, and all sampling activities
- Site restoration: 326 days; the backfilling and compaction of the site requires the longest duration. Moving the overburden stockpile back to the excavation site and loading/hauling borrow material from the borrow pit require less time
- Demobilize: 10 days.

Site description:

- Surface area of combined waste sites: 640 ft by 540 ft
- Depth of clean overburden: 11 ft below ground surface
- Total depth of excavation: 150 ft
- Trench lengths:
  - The 216-B-23 to 216-B-28 Trenches are 500 ft each
  - The 216-B-52 Trench is 580 ft
- Total volume of excavation including terraces and haul roads: 7,230,112 yd^3
- Contamination - higher level zone requiring 7:1 mixing:
  - Depth is 11 to 15 ft below ground surface
  - Width is 14 ft
  - Length is one half of the trench length (for the 216-B-23 to 216-B-28 Trenches it is 250 ft, for the 216-B-52 Trench it is 290 ft)
  - Volume of contamination: 3,716 yd^3 in place
  - Volume after mixing: 29,728 yd^3
- Contaminated soil not requiring mixing volume: 1,788,284 yd^3

- Total volume of contaminated waste moved to the ERDF: 1,818,012 yd^3
- Overburden soil to be removed during excavation: 5,412,100 yd^3
- Borrow backfill from on-site pit: 1,818,012 yd^3.

Cost breakdown:

• Mobilization:	$ 1,431,305
• Monitoring and sampling:	$ 5,218,622
• Solids collection:	$ 40,776,865
• Queue area operations:	$ 28,852,674
• ERDF disposal:	$235,238,407
• Site restoration:	$ 17,353,374
• Revegetation:	$ 691,457
• Demobilization:	$ 110,331
• Construction staff:	$ 6,942,293
• Project management:	$ 2,732,875
• Miscellaneous costs:	$ 52,574
Total:	$339,400,757.

D3.3.3 Surveillance and Maintenance

No costs associated with surveillance and maintenance of Alternative 3, because all contamination will be removed from the site.

D3.4 ALTERNATIVE 4 – CAPPING

Barriers will be constructed over groups of trenches or cribs. For cost estimating purposes, each waste site grouping will include the Modified RCRA Subtitle C Barrier, also referred to as the Modified RCRA Subtitle C Barrier, because it includes intrusion-deterrent features, over individual waste sites and will include ET capillary barriers between the waste sites and around the periphery. For planning purposes, the Modified RCRA Subtitle C Barriers are to cover the full length of the trench and are to be 30 ft wide. Cribs are to have 60 x 60 ft Modified RCRA Subtitle C Barriers. The ET capillary barrier will extend 75 ft beyond the footprint of the cribs. Figure D-1 depicts the model used to estimate barrier cost. Final barrier configuration will be established during the design phase.

D3.4.1 General Assumptions

The general assumptions for Alternative 4 are as follows.

- The field work, such as mobilization/demobilization, borrow site excavation, barrier fill, and revegetation and some field work for the postconstruction work will be contracted to an FP contractor. The project management, RCT support, sampling, and safety oversight will be performed by FH.

- Mobilization and startup includes site training, mobilization of equipment and personnel, installing temporary construction fences, construction of access roads, setting up office, and storage trailers with utilities.
- Air sampling will be performed during the construction of the first layer of the barrier. A minimum of two samples will be taken per day. The planning cost is $520 per sample. The sampling crew is made up of one sampler and one RCT.
- Revegetation of the waste site barrier includes planting native dry-land grass using tractors with seed drills and hand broadcasting, hand-planting sagebrush seedlings, and irrigating four times in the spring or early summer. All disturbed areas such as around the barrier, stockpile, staging areas, and access roads are to be replanted.
- The FH project management team is made up of a part-time project manager, a full-time field supervisor, and part-time engineering support. The Quality Assurance, Radiological Control, and Safety organizations also provide oversight, along with other support for contract management and project controls. The duration of this work is based on total project duration.
- Demobilization shall include demobilization of equipment and personnel and removing temporary construction fences, access roads, and office/storage trailers.
- There are two on-site sources for the fill materials to construct the three soil layers. The source for engineered fill is located approximately 5 mi from the BC Cribs and Trenches Area and is assumed to have a sufficient quantity of fill for this project. The source for the silt required for Layers 1 and 2 is located about 7 mi away.
- The sand, drainage gravel, gravel filter, crushed base course, fractured basalt, and asphalt pavement will be supplied by off-site vendors or from commercial gravel pits. These materials are delivered to the waste site by the vendor.
- All barrier sites are considered to have settled and are compacted enough to support construction of a barrier without further settling.
- Sites will not require preleveling before the start of construction of the barrier.
- The Modified RCRA Subtitle C Barrier portion of the cap will be made up of eight different layers, as follows.
  - The bottom layer, Layer 8, will be constructed of 40 in. (nominal thickness) of engineered fill to accommodate surface irregularities. Construction of the engineered fill requires the excavation of suitable borrow material from an on-site pit source. The estimated time to complete the fill is based on the production rate of a 4 to 5 yd^3 loader excavating at the pit. All material is screened with a grizzly (rock screen)

mounted on a surge bin to remove 4-in. or larger rocks. Six semitractor trucks with 20-yd^3 bottom-dump trailers are needed to keep up with the loader. A truck with a 6,000-gal water trailer provides dust control at the pit. The production rate for this work is 185 loose yd^3/h. The spreading and compaction equipment used at the barrier is a 250 to 300-hp bulldozer, with a U-blade to spread fill and two 12-ton vibratory tandem rollers. Dust control is maintained by a truck with a 6,000-gal water trailer.

To produce a smooth surface that will prevent low areas, the surface of engineered fill is fine graded. Work involves a 100 to 150-hp bulldozer with laser controls, one 4- to 5-yd^3 loader, one 12-ton vibratory single-drum roller, and a water tanker. The production rate is 2,500 yd^2/h for the engineered-fill surface area. One laborer supports the bulldozer operator and water truck. Two engineer technicians set up the grade and elevation control.

- The next layer, Layer 7, will consist of 4 in. of crush surfacing base course. This material will come from a commercial source and will be delivered and truck-spread at the construction site. The delivered cost of material, based on vendor quotes, is \$17.61/yd^3. The equipment used for this work is a motor grader, a 12-ton vibratory tandem roller, and a truck with a 6,000-gal water trailer. Two equipment operators and one truck driver operate the equipment. One laborer supports the grader operator as a grade checker and to help unload trucks. The production rate for this work is 641 yd^2/h.

- Layer 6 is the 6-in. asphalt concrete pavement (ACP) layer. The material is from a commercial source and is delivered to the site using the supplier's trucks. The delivered cost of material, based on vendor quotes, is \$45.50/T. The ACP used has twice (6 to 8 percent) the normal amount of asphalt in the mix design. The other equipment used to construct this layer is a paving machine and two 12-ton vibratory tandem rollers. The production rate for this work is 100 T/h. Three equipment operators operate the equipment, while six laborers help unload trucks, rake asphalt, or support grade control.

- Layer 5 is the lowest layer of the three drainage layers that are constructed on top of the ACP layer. Work covers the spreading, compacting, and grading of the drainage gravel. The gravel will come from a commercial source and will be delivered and spread by the supplier's trucks on the ACP. The delivered cost of material, based on vendor quotes, is \$17.16/yd^3. The equipment used to construct this layer is a motor grader, two 12-ton vibratory tandem rollers, and a truck with a 6,000-gal water trailer. The production rate for this work is 208 yd^3/h. Three equipment operators and one truck driver operate the equipment. One laborer supports the grader operator as a grade checker and to help unload trucks.

- Layer 4 is the middle layer of the three drainage layers. Work covers the spreading, compacting, and fine grading of the one-quarter-in. minus gravel filter. The material is from a commercial source and is delivered to the site by the supplier. The delivered cost of material, based on vendor quotes, is \$16.70/yd^3. The equipment used to construct this layer is a motor grader, two 12-ton vibratory tandem rollers, and a truck with a 6,000-gal water trailer. The production rate for this work is 208 yd^3/h. Three equipment operators and one truck driver operate the equipment. One laborer supports the grader operator as a grade checker and to help unload trucks.

- Layer 3 is the top layer of the three drainage layers. Work covers the spreading, compacting, and fine grading of the filter sand used for Layer 3. The delivered cost of material, based on vendor quotes, is $16.70/$yd^3$. The equipment used to construct this layer is a motor grader, two 12-ton vibratory tandem rollers, and a truck with a 6,000-gal water trailer. The production rate for this work is 208 yd^3/h. Three equipment operators and one truck driver operate the equipment. One laborer supports the grader operator as a grade checker and to help unload trucks.

  Layer 3 will be fine graded to produce a smooth surface before the geotextile is placed. Work involves a 100 to 150-hp bulldozer with laser controls, a 4 to 5-yd^3 loader, one 12-ton vibratory single-drum roller, and a water tanker. The production rate is 2,500 yd^2/h for the engineered fill surface area. One laborer supports the bulldozer operator and water truck. Two engineer technicians set up the grade and elevation control.

  A geotextile is placed on top of Layer 3. This item of work covers the placement of a needle-punched 120-mil-thick polypropylene geotextile over the sand filter layer. The production rate is 150 yd^2/h. Three laborers place and splice the fabric.

- The construction of Layer 2 involves excavating and hauling the silt from the on-site pit to the barrier. This layer is 20 in. deep. The production rate is based on a 4 to 5 yd^3 loader excavating and loading at the pit. Seven trucks are 20-yd^3 bottom-dump trailer and semitractor combinations. The production rate for this work is 185 loose yd^3/h, based on the production of the loader. At the barrier, the silt is spread with a 200 to 250-hp low ground pressure bulldozer. The silt is scarified to prevent over compaction. Dust control at the pit and the barrier is maintained by trucks with 6,000-gal water trailers.

- Layer 1 requires a 20-in.-deep layer of fill material made up of silt with 15 percent pea gravel added by weight. The silt is excavated with a 4 to 5 yd^3 loader, and two dump trucks haul it from the site silt source to a process area near the pit. Pea gravel from a commercial source is delivered and stockpiled at the process area. The delivered cost of material, based on vendor quotes, is $18.71/$yd^3$. A 4 to 5 yd^3 loader and a pug mill with a belt loader are used to mix the silt and gravel. The hauling from the process area is the same as that described for Layer 2. Spreading is the same as for Layer 2.

• The ET/capillary cap portion of the barrier will be made up of three different layers.

  - The bottom layer will be constructed of 40 to 68 in. (nominal thickness to accommodate surface irregularities and match the height of the top drainage layer of the Modified RCRA Subtitle C Barrier) of engineered fill. The process will be the same as for the Modified RCRA Subtitle C Barrier Layer 8.**changed Cap to Barrier when it says Modified RCRA Subtitle C**

- The middle layer will be constructed of 20 in. of silt fill. The process will be the same as for the Modified RCRA Subtitle C Barrier Layer 2.

- The top layer will be constructed of 20 in. of silt/pea gravel fill. The process will be the same as for the Modified RCRA Subtitle C Barrier Layer 1.

- The side slopes of the barrier will be covered with fractured basalt, 1 ft deep, and engineered fill, 1 ft deep.

  - The side slopes of the barrier are graded before any engineered fill or fractured basalt is placed. The work involves a 100 to 150-hp bulldozer with laser controls, a 4 to 5-yd^3 loader, one 12-ton vibratory single-drum roller, and a water tanker. The production rate is 2,500 yd^2/h for the engineered fill surface area. One laborer supports the bulldozer operator and the water truck. Two engineer technicians set up the grade and elevation control.

  - The construction of the engineered fill for the side slope follows the grading of the side slope. A 4 to 5 yd^3 loader excavates the fill at the borrow pit. All fill material is screened with a grizzly (rock screen) mounted on a surge bin to remove 4-in. or larger rocks. Four semitractor trucks with 20-yd^3 bottom-dump trailers are needed to keep up with the loader. A truck with a water trailer provides dust control. The production rate for this work is 125 loose yd^3/h. The spreading and compaction equipment used at the barrier is a 250 to 300-hp bulldozer with a U-blade to spread fill and one 12-ton vibratory single-drum rollers.

  - The fractured basalt will come from a commercial source and will be delivered and stockpiled at the construction site. The delivered cost of material, based on vendor quotes, is \$21.61/yd^3. One loader and one 300-hp bulldozer are used to place the basalt on the fill slope. One laborer supports the work. The production rate is 70 loose yd^3/h. A quarter time water truck and driver are used for dust control.

- An allowance of \$100,000 per barrier site is used to cover performance monitoring features that are expected to be required. The instruments include lysimeters, settlement gauges, or other instruments required to monitor the barriers. This includes electrical service to the site.

- After completion of the barrier construction work, a 4-ft steel post with chain fence is to be built around the site. The fence location is at the toe of the barrier slope.

- During the construction of the barrier, compaction testing will be performed on the three layers of fill. The lower level will require that a minimum level of compaction has been reached, while the top two layers will be tested to ensure that the fill does not become over compacted.

D3.4.2 Site 216-B-23 to -28 and 216-B-52 Trenches

This group of trenches will be treated as one barrier site; therefore, they are handled as one estimate. The trenches covered by this estimate are the 216-B-23, 216-B-24, 216-B-25, 216-B-26, 216-B-27, 216-B-28, and 216-B-52 Trenches.

The site work is estimated to take 241 days or 12 months. The remediation time is based on the following critical path items:

- Mobilization: 15 days
- Construction of Layer 8 engineered fill: 125 days
- Construction of Layer 7 base course: 1 day
- Construction of Layer 6 ACP: 3 days
- Construction of Layer 5 drainage gravel: 1 day
- Construction of Layer 4 gravel filter: 2 days
- Construction of Layer 3 sand and geotextile: 5 days
- Construction of Layer 2 silt: 30 days
- Construction of Layer 1 silt/pea gravel: 26 days
- Construction of Side Slope: 17 days
- Revegetation: 6 days
- Demobilize: 1 0 days.

Site description:

- Surface area of combined waste sites: 640 by 580 ft
- Cap overlap: 75 ft on all sides
- Trench lengths:
  - The 216-B-23 to 216-B-28 Trenches are 500 ft each
  - The 216-B-52 Trench is 580 ft
- Modified RCRA Subtitle C Barrier width: 30 ft for each trench
- Engineered fill (Layer 8 and side slope) volume: 165,840 yd^3
- Layer 7 base course volume: 5,800 yd^3
- Layer 6 ACP: 2,480 Tons
- Layer 5 drainage gravel volume: 1,110 yd^3
- Layer 4 gravel filter volume: 1,110 yd^3
- Layer 3 sand volume: 1,110 yd^3
- Layer 2 silt volume: 44,550 yd^3
- Layer 1 silt/pea gravel volume: 43,460 yd^3

- Side-slope fractured basalt volume: 5,770 yd^3.

Cost breakdown

- Mobilization: $ 195,135
- Monitoring and Sampling: $ 76,041
- Solids Collection: $ 0
- Queue Area Operations: $ 0
- ERDF Disposal: $ 0
- Site Restoration: $4,202,933
- Revegetation: $ 349,510
- Demobilization: $ 3,581
- Construction Staff: $ 798,613
- Project Management: $ 403,815
- Miscellaneous Costs: $ 13,590

Total: $6,043,218.

D3.4.3 Surveillance and Cap Maintenance

The costs associated with surveillance and cap maintenance are expected to be equal to the site inspection/surveillance and existing maintenance cost items under Alternative 2. Refer to the Alternative 2 descriptions and assumptions for these cost items.

Alternative 4 Activity Frequency				
Item	Alternatives 4			
	Annually	per 3 Years	per 5 Years	per 30 Years
Institutional Controls	Y			
Perform Existing Barrier Cover Inspection	Y			
Conduct Radiation Survey of Surface Soil			Y	
Maintain Existing Barrier Cover	Y			
Conduct Vadose Zone Monitoring			Y	
Prepare and Issue Sampling Reports			Y	
Conduct Site Reviews			Y	
Construct Decontamination Pad		Y		
Perform Ground Water Monitoring			Y	

D3.5 ALTERNATIVE 5 – PARTIAL REMOVAL WITH CAPPING

Individual waste sites are excavated to remove near-surface contamination. Then, following backfill of the excavation, ET capillary barriers are constructed to address the groundwater threat posed by deep mobile contamination.

D3.5.1 General Assumptions

The general assumptions for Alternative 5 are as follows.

- The field work such as mobilization/demobilization, excavation, backfill, barrier fill, and revegetation, and some for the postconstruction work will be contracted to an FP contractor. The project management, RCT support, sampling, and safety oversight will be performed by FH. The waste disposal work involved with hauling from the site to the ERDF and the ERDF dumping cost/fees will be performed by the Environmental Restoration Contractor responsible for the ERDF.

- Mobilization and startup include site training; mobilization of equipment and personnel; installing temporary construction fences; construction of staging/container storage areas and access roads; setting up office, change, and storage trailers with utilities, truck scales, temporary survey buildings, and decontamination areas.

- For trenches and cribs, only the near-surface contamination will be excavated and transported to the ERDF. Trenches will be excavated to 15 ft; the cribs will be excavated to 20 ft. The upper 10 to 11 ft of the excavation will be considered overburden and will be left on site. For the trenches, half of the contaminated region between 11 and 15 ft requires downblending at a 7:1 ratio. For the cribs, the entire contaminated region between 11 and 20 ft requires downblending at the same ratio.

- The sections of the trenches or cribs that have contamination that does not require mixing will be excavated by the following process.

  - The overburden will removed using three excavation crews. Each crew will have one 2 to 3-yd^3 hydraulic excavator, two 15 to 20-yd^3 haul trucks, and a water truck to excavate and stockpile the overburden. The labor will be one operator and three truck drivers. Each crew will excavate and stockpile 127 yd^3/h.

  - The contaminated waste will be excavated using four crews. Each crew will have one 2 to 3-yd^3 hydraulic excavator to excavate the waste and load it into ERDF containers. The contaminated soil will be placed directly into lined ERDF containers and hauled from the excavation site. A highway truck with water tank trailer is used to control dust during this activity. Crew labor is made up of one operator, one laborer, and one truck driver. The production rate for one crew is 55 yd^3/h. An FH RCT supports the work at 1.5 h per excavation crew hour.

- The sections of the trenches and cribs that require a higher level of contamination to be mixed before excavation and disposal will follow the same process as that described for Alternative 3. The contaminated waste will require mixing at a ratio of 7 parts "near-clean" soil to 1 part contaminated soil and will use the following process.

  - Starting at one of the planned trench excavating sites, one 2 to 3-yd^3 excavator excavates the overburden from a 20 to 30-ft length of trench. The overburden is stacked on one side of the trench within easy reach of the excavator (A).

  - When the overburden excavation gets within 1 ft of the layer to be removed, a second long-reach excavator (B) with a 1 to 1.5-yd^3 bucket is brought in to mix the waste to the required ratio and direct load the haul trucks with ERDF containers.
  - Excavator A continues to strip the trench of overburden and place the soil in the mixing zone. The excavator also can move soil from the initial stock pile into the mixing zone.
  - Excavator B stays on one side of the trench, with haul trucks operating on the same side.
  - This process continues, moving down the length of the trench.
  - A water truck is used to control dust at the excavation site.
  - An FH RCT supports the work at 1.5 h per excavation crew hour.

- Air sampling will be performed during the excavation of contaminated soil. A minimum of two samples will be taken per day. The planning cost is $520 per sample. The sampling crew is made up of one sampler and one RCT.

- Soil samples of the overburden will be taken, from ERDF containers, and for verification that the excavation has been completed. The soil sampling cost has been developed as follows:

  - Noncontaminated soil sampling:
    - Maximum of 6 samples or 1 sample per yd^3, whichever is less
    - The quality assurance sample required is 1
    - The planning cost is $1,262 per sample
    - The soil being sampled is the overburden that is uncontaminated and that will not be removed from the site.
  - Sampling required for waste going to the ERDF:
    - One sample is required for every 70 containers
    - There will be a minimum of 6 samples per site
    - The number of quality assurance samples required is a minimum of 1 or 5 percent of the total of ERDF samples, whichever is greater
    - The planning cost is $452 per sample.
  - Preverification process sampling:
    - One sample will be required per 2,500 m^2 (50 x 50 m or 26,899 ft^2)
    - There will be a minimum of 6 samples per site
    - The number of quality assurance samples required is a minimum of 2 or 5 percent of the total of samples, whichever is greater
    - The planning cost is $2,227 per sample

  - These samples are the preliminary samples needed to determine if all of the required waste has been removed from a site being excavated
  - This process is expected to happen twice during the excavation process
  - If the samples show that the site has met the requirement, then the verification process will start.

- Verification process sampling:
  - One sample will be required per 625 m^2 (25 x 25 m or 6,724 ft^2)
  - There will be a minimum of 6 samples per site
  - The number of quality assurance samples required is a minimum of 2 or 5 percent of the total of samples, whichever is greater
  - The planning cost is $7,856 per sample for onsite laboratory analysis and $1,458 for offsite laboratory analysis and shipping (based on 6 samples being process at one time); for a total of $9,314 per sample
  - These samples are the final samples needed to determine if all of the required waste has been removed from a site being excavated
  - This process happens once during the excavation process.

- Sampling crews:
  - Verification Sampling – 1 h for each sample taken by a crew made up of one FH RCT and one sampler technician.
  - Other sampling (air, ERDF, noncontaminated) – 1 h for each sample taken by a crew made up of one FH RCT and one sampler technician.

- The ERDF container handling and loading process starts with a site haul truck picking up an empty container at the staging area. The container is moved to a preparation area, where laborers install a bed liner, and then it is inspected by a half-time RCT. The haul truck takes the container to the loading area. After the container is loaded, the liner is sealed and the container is secured by laborers. The container is moved to the survey building, where a team of three RCTs inspect and survey the container and truck for contamination. From there the haul truck and container are weighed on a platform scale and then driven to the storage area. The container is unloaded from the truck at the storage area. Three trucks are required to support each contaminated-excavation crew.

- ERDF disposal fee and transportation and handling costs are estimated at $980 per container. An Environmental Restoration Contractor driver and truck/trailer will move a loaded container to the ERDF and then will take an empty container back to the staging area. The estimated costs include the rental of the containers used. For planning purposes, the capacity of an ERDF container is 11 bank yd^3 or 12.7 loose yd^3 of contaminated waste.

- Backfill of the excavated area is performed by three different operations.

  - The moving of the stockpiled overburden back to the excavation site will require one crew. The equipment used by the crew is one 4 to 5 yd^3 loader and two haul trucks. Labor is one operator and two truck drivers. The production rate for one crew is 185 yd^3/h.

- The moving of borrow material to the excavation site typically is performed by one crew hauling from an on-site pit source. The equipment used by a crew is one 4 to 5 yd^3 loader, six 20-yd^3 highway truck/trailers, and one water truck. Labor is one operator and seven truck drivers. The production rate for one crew is 185 yd^3/h.

- Spreading and compaction of the backfill at the site is performed by one crew. The equipment used per crew is one 300-hp bulldozer and one 6,000-gal water truck/trailer. Labor is made up of one operator, one truck driver, and one laborer. The production rate for one crew is 185 yd^3/h.

- The FH project management team is made up of a part-time project manager, a full-time field supervisor, and part-time engineering support. The Quality Assurance, Radiological Contamination, and Safety organizations also provide oversight, along with other support for contract management and project controls. The duration of this work is based on total project duration.

- Demobilization includes demobilization of equipment and personnel and removing temporary construction fences, staging/container storage areas, access roads, office/change/storage trailers, truck scales, temporary survey buildings, and decontamination areas.

- There are two on-site sources for the fill materials to construct the three layers. The source for engineered fill is located approximately 5 mi from the BC Cribs and Trenches Area and is assumed to have a sufficient quantity of fill for this project. The source for the silt required for Layers 1 and 2 is located about 7 mi away.

- All barrier sites are considered to have settled and are compacted enough to support construction of a barrier without further settling.

- Sites will not require preleveling before the start of barrier construction.

- Construction of the engineered fill requires the excavation of suitable borrow material from an on-site pit source. This layer is 40 in. deep (nominal thickness to accommodate surface irregularities). The estimated time to complete the fill is based on the production rate of a 4 to 5-yd^3 loader excavating at the pit. All material is screened with a grizzly (rock-sorting device) mounted on a surge bin to remove 4-in. or larger rocks. Six semitractor trucks with 20-yd^3 bottom-dump trailers are needed to keep up with the loader. A truck with a 6,000-gal water trailer provides dust control at the pit. The production rate for this work is 185 loose yd^3/h. The spreading and compaction equipment used at the barrier is a 250 to 300-hp bulldozer with a U-blade to spread fill and two 12-ton vibratory tandem rollers. Dust control is maintained by a truck with a 6,000-gal water trailer.

- To produce a smooth surface that will prevent low areas, the surface of engineered fill is fine graded. Work involves a motor grader, a 4 to --5 yd^3 loader, two 12-ton vibratory tandem rollers, and a water tanker. The production rate is 5,000 yd^2 per day for the engineered fill surface area. One laborer supports the grader operator as a grade checker.

- The construction of Layer 2 involves excavating and hauling the silt from the on-site pit to the barrier. This layer is 20 in. deep. The production rate is based on a 4 to 5-yd^3 loader excavating and loading at the pit. Seven trucks are 20 yd^3 bottom-dump trailer and semitractor combinations. The production rate for this work is 185 loose yd^3/h, based on the production of the loader. At the barrier, the silt is spread with a 200 to 250-hp low ground pressure bulldozer. The silt is scarified to prevent over compaction. Dust control at the pit and the barrier uses trucks with 6,000-gal water trailers.

- Layer 1 requires a 20-in.-deep layer of fill material made up of silt with 15 percent pea gravel added by weight. The silt is excavated and hauled from an on-site silt source to a process area near the barrier. The excavation and hauling is the same as that described for Layer 2. Pea gravel from a commercial source is delivered and stockpiled at the process area. A 4 to 5 yd^3 loader and a pug mill with a belt loader are used to mix the silt and gravel. Three trucks that are 20-yd^3 bottom-dump trailer and semitractor combinations haul from the pug mill to the barrier. Spreading is the same as for Layer 2.

- This item of work covers the placement of fractured basalt on the face of the side slopes of the barrier fill. The material is from a commercial source and is delivered to the site by the supplier. One loader and one end-dump truck are used to place the basalt on the fill slope. Two laborers support the work. The production rate is 32 loose yd^3/h.

- An allowance of $100,000 per barrier site is used to cover performance monitoring features that are expected to be required. The instruments include lysimeters, settlement gauges, or other instruments required to monitor the barriers. This includes electrical service to the site.

- After completion of the barrier construction work, a 4-ft steel post with a chain fence is to be built around the site. The fence location is at the toe of the barrier slope.

- During the construction of the barrier, compaction testing will be performed on the three layers of fill. The lower level will require that a minimum level of compaction has been reached, while the top two layers will be tested to ensure that the fill does not become over compacted.

- Revegetation of the waste site barrier includes planting native dry-land grass using tractors with seed drills and hand broadcasting, hand-planting sagebrush seedlings, and irrigation four times in the spring or early summer. All disturbed areas such as around the barrier, stockpile, staging areas, and access roads are to be replanted.

D3.5.2 Site 216-B-23 to -28 and 216-B-52 Trenches

This group of trenches will be treated as one barrier site; therefore, they are handled as one estimate. The trenches covered by this estimate are the 216-B-23, 216-B-24, 216-B-25, 216-B-26, 216-B-27, 216-B-28, and 216-B-52 Trenches.

The site work is estimated to take 325 days or 16 months. The remediation time is based on the following critical path items:

- Mobilization: 15 days
- Contaminated Waste Excavation: 4 days; other items of work that occur during this time are stripping overburden, hauling the containers to the survey area, storing and then moving them to the ERDF, and all sampling activities
- Contaminated Waste Excavation (7:1 mixing excavation): 127 days; other items of work that occur during this time are hauling the containers to the survey area, storing and then moving them to the ERDF, and all sampling activities
- Backfill of Excavation: 12 days; other items of work that occur during this time are excavation/hauling from a borrow site and the overburden stockpile
- Construction of engineered fill: 94 days
- Construction of Layer 2 silt layer: 27 days
- Construction of Layer 1 silt/pea gravel layer: 24 days
- Construction of Side Slope: 7 days
- Revegetation: 5 days
- Demobilize: 10 days.

Site description:

- Surface area of combined waste sites: 640 by 580 ft
- Cap overlap: 75 ft on all sides
- Trench lengths:
  - 216-B-23 to 216-B-28 are 500 ft each
  - 216-B-52 is 580 ft
- Contamination:
  - Depth is 11 to 15 ft below ground surface
  - Width is 14 ft
  - Length is the same as the trench length
  - Volume of contamination not requiring mixing: 6895 yd^3
  - Volume of contamination, higher level zone requiring 7:1 mixing (after mixing): 29,728 yd^3
- Overburden volume: 35,973 yd^3

- Borrow volume: 36,623 yd^3
- Trench backfill volume: 72,596 yd^3
- Engineered fill volume: 83,825 yd^3
- Layer 2 silt volume: 40,287 yd^3
- Layer 1 silt/pea gravel volume: 39,223 yd^3
- Side-slope fractured basalt volume: 3,785 yd^3.

Cost breakdown

• Mobilization:	$ 244,307
• Monitoring and sampling:	$ 586,872
• Solids collection:	$ 2,103,647
• Queue area operations:	$ 1,912,760
• ERDF disposal:	$ 4,743,457
• Site restoration:	$ 2,623,547
• Revegetation:	$ 131,286
• Demobilization:	$ 38,186
• Construction staff:	$ 1,076,968
• Project management:	$ 544,564
• Miscellaneous costs:	$ 13,590
Total:	$14,019,218

D3.5.3 Surveillance and Cap Maintenance

The costs associated with surveillance and cap maintenance are expected to be equal to the site inspection/surveillance and existing maintenance cost items under Alternative 2. Refer to the Alternative 2 descriptions and assumptions for these cost items.

Alternative 5 Activity Frequency				
Item	Alternatives 5			
	Annually	per 3 Years	per 5 Years	per 30 Years
Institutional Controls	Y			
Perform Existing Barrier Cover Inspection	Y			
Conduct Radiation Survey of Surface Soil			Y	
Maintain Existing Barrier Cover	Y			
Conduct Vadose Zone Monitoring			Y	
Prepare and Issue Sampling Reports			Y	
Conduct Site Reviews			Y	
Construct Decontamination Pad		Y		
Perform Ground Water Monitoring			Y	

D3.6 MISCELLANEOUS SITES – 200-E-114 PIPELINE AND 200-E-14 SIPHON TANK

The proposed remediation methods for these two sites are unique to the Hanford Site. Some of the global cost assumptions discussed above will apply to these sites.

D3.6.1 200-E-114 Pipeline Removal – Alternative 3

This alternative will remove the pipeline and backfill and replant the site.

- The pipeline is excavated to an average depth of 10 ft to expose the pipe. The pipe to be removed is a 2-in/-diameter steel pipe approximately 1,200 ft in length. For planning purposes, the soil is considered contaminated if it is within 1 ft of the pipe. The trench will be a minimum of 2 ft wide at the bottom of the trench, and the side walls will be laid back on a 1.5:1 slope.

- Once the pipe is exposed, it will cut into 1 to 2-ft sections with a shear mounted on a hydraulic excavator. After that the pipe will be excavated with the remaining contaminated soil and placed into ERDF containers.

- The excavation of the overburden soil and contaminated waste; the handling of ERDF containers; sampling; back filling; and revegetation of the excavation will be the same as is described in Section D3.3.1 for shallow excavation RTD sites.

- No mixing of the contaminated waste is expected for the site.

D3.6.2 200-E-114 Pipeline Barrier – Alternative 4

This alternative will leave the pipeline in place and construct a Modified RCRA Subtitle C Barrier for the full length of the pipe.

- The barrier will have a 52-ft width at the ground surface and a 10-ft width on top. The length will be approximately 1,200 ft.

- The construction of the barrier will be the same as that described in Section D3.4.1.

- The side slopes for the barrier will be the same as that described in Section D3.4.1.

D3.6.3 200-E-14 Siphon Tank Removal – Alternative 3

This alternative removes the sludge from the tank, demolishes and removes the tank, backfills the excavation, and replants the site.

- The sludge is removed from the underground tank using the same process that is proposed for the 241-Z-361 Settling Tank. This process is described in DOE/RL-2003-52, *Tank 241-Z-361 Engineering Evaluation/Cost Analysis*. An AEA Technology[1] fluidics system will be used to remove sludge from the tank. The waste will be packaged to Hanford Site requirements and transferred to interim on-site storage. The cost of this process is $4,601,930 to remove sludge from the tank and package the waste. The cost does not include interim storage or final disposal.

- The tank is then completely excavated and demolished. The excavation process is the similar to the process for excavation of the pipeline, described in Section D3.5.1.

- The underground tank is a concrete tank with 1-ft-thick walls and is 27 ft long by 13 ft wide and 9.5 ft high. There is 7 ft of overburden on top of the tank. The soil 1 ft outside of the tank is expected to be contaminated and will be removed to the ERDF. Demolition waste from the tank also will be removed to the ERDF. None of the excavation or demolition waste will require mixing to meet ERDF requirements.

- The concrete tank will be demolished using an impact hammer and pulverizer mounted on a hydraulic excavator. The debris will be reduced in size to meet ERDF requirements and will be loaded into ERDF containers.

- The handling of ERDF containers, sampling, back filling, and revegetation of the excavation will be the same as describe in Section D3.3.

D3.6.4 200-E-14 Siphon Tank Barrier – Alternative 4

This alternative will leave the underground tank in place and construct a Modified RCRA Subtitle C Barrier over the tank.

- Before the barrier is constructed, the tank will have the manholes excavated and opened, and then control density fill (CDF) will be pumped into tank. The sludge in the tank will not be removed.
- The construction of the barrier will be the same as that described in Section D3.4.1.
- The side slopes for the barrier will be the same as that described in Section D3.4.1.

D3.6.5 200-E-14 Siphon Tank Sludge Removal and Barrier – Alternative 5

This alternative removes the sludge from the tank, fills the tank with CDF, and constructs an ET capillary barrier over the tank.

- The sludge will be removed from the tank as described in Section D3.5.3, Alternative 3.

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[1] AEA Technology is a trademark of AEA Technology plc, Winfrith, United Kingdom.

- The tank will filled with CDF as described in D3.5.4, Alternative 4.
- The construction of the barrier will be the same as described in Section D3.4.1.
- The side slopes for the barrier will be the same as described in Section D3.4.1.

D3.6.6 Surveillance and Maintenance

The costs associated with surveillance and maintenance are expected to be equal to the site inspection/surveillance and existing maintenance cost items under Alternative 2. The only exception is long-term groundwater monitoring, which will not be included for these two sites. Refer to the Alternative 2 descriptions and assumptions for these cost items.

Miscellaneous Sites Activity Frequency

Item	Miscellaneous Sites - Alt 2,4,& 5			
	Annually	per 3 Years	per 5 Years	per 30 Years
Institutional Controls	Y			
Perform Existing Barrier Cover Inspection	Y			
Conduct Radiation Survey of Surface Soil			Y	
Maintain Existing Barrier Cover	Y			
Conduct Vadose Zone Monitoring			Y	
Prepare and Issue Sampling Reports			Y	
Conduct Site Reviews			Y	
Construct Decontamination Pad		Y		
Perform Ground Water Monitoring	N	N	N	N

D4.0 REFERENCES

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Site Stabilization Agreement for All Construction Work for the U.S. Department of Energy at the Hanford Site, 1984, as amended, commonly known as the Hanford Site Stabilization Agreement (original title, *Site Stabilization Agreement, Hanford Site, between J.A. Jones Construction Services Company and Morrison-Knudsen Company, Inc., and the Building and Construction Trades Department of the AFL-CIO and its affiliated international unions, and the International Brotherhood of Teamsters, Chauffeurs, Warehousemen, and Helpers of America*).

The Social Security Act of 1935, 26 USC 21, et seq. (*Federal Insurance Contributions Act* or FICA.

Figure D-1. Alternative 4 Cap.

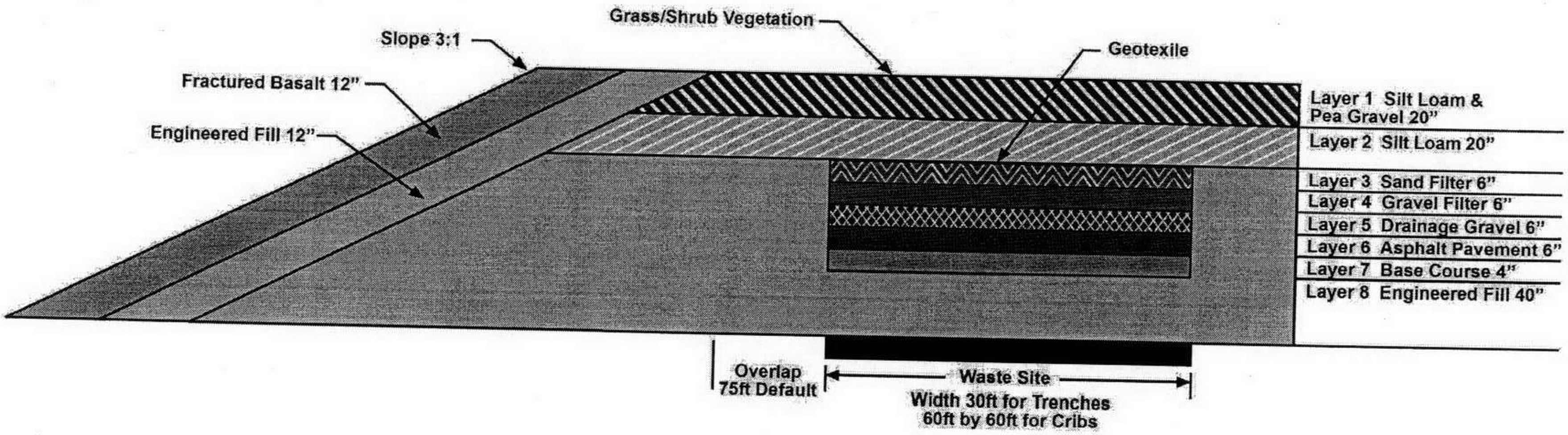

Table D-1. Capital Cost Estimate Breakdown ($1000).

Site	Alter-native	Mobilization	Monitoring & Sampling	Solids Collection	Queue Area Operations	ERDF Disposal	Site Restoration	Revegetation	Demobilization	Construction Staff	Project Management	Misc Cost	Total
Trenches 216-B-23 to -28, and 216-B-52	Alt 3	$1,431	$5,219	$40,777	$28,853	$235,238	$17,353	$691	$110	$6,942	$2,733	$53	$339,401
	Alt 4	$195	$76	$0	$0	$0	$4,203	$350	$4	$799	$404	$34	$6,063
	Alt 5	$244	$586	$2,104	$1,913	$4,744	$2,623	$131	$38	$1,077	$545	$34	$14,039.
Cribs 216-B-14 to -19	Alt 3	$1,425	$3,655	$27,042	$11,971	$90,277	$18,375	$652	$88	$3,984	$1,568	$35	$159,074
	Alt 4	$130	$27	$0	$0	$0	$1,617	$72	$9	$345	$174	$34	$2,408
	Alt 5	$200	$294	$2,162	$1,890	$4,016	$1,114	$66	$37	$706	$357	$14	$10,856
Trench 216-B-58	Alt 3	$100	$188	$108	$27	$207	$80	$42	$24	$142	$86	$17	$1,021
Trench 216-B-54	Alt 3	$100	$188	$108	$27	$20	$80	$42	$24	$142	$86	$17	$1,021
Trenches 216-B-54 and -58	Alt 4	$107	$10	$0	$0	$0	$708	$39	$2	$186	$94	$34	$1,180
Trenches 216-B-53A and -53B	Alt 3	$100	$191	$114	$31	$233	$85	$42	$24	$148	$89	$17	$1,073
	Alt 4	$103	$8	$0	$0	$0	$497	$33	$12	$149	$75	$34	$880
Trenches 216-B-29 to -34	Alt 3	$1,440	$5,855	$45,857	$33,234	$274,621	$18,900	$750	$111	$7,926	$3,120	$58	$391,871
	Alt 4	$185	$65	$0	$0	$0	$3,976	$138	$3	$736	$372	$14	$5,489
	Alt 5	$244	$504,902	$1,972,947	$1,603	$3,975	$2,599	$131	$38	$925	$467	$73	$12,532
Trenches 216-B-20 to -22	Alt 3	$1,45	$3,042	$21,581	$12,214	$99,636	$12,130	$515	$109	$3,341	$1,315,332	$32	$155,321
	Alt 4	$138	$32	$0	$0	$0	$2,061	$85	$3	$414	$209	$14	$2,957
	Alt 5	$174	$256	$987	$801	$1,989	$903	$53	$37	$378	$191	$35	$5,804
Pipeline 200-E-114	Alt 3	$138	$156	$20	$3	$30	$5	$17	$42	$81	$49	$16	$557
	Alt 4	$114	$7	$0	$0	$0	$908	$53	$3	$202	$102	$34	$1,422
Siphon Tank 200-E-14	Alt 3	$129	$151	$4,611	$3	$20	$3	$34	$42	$67	$41	$14	$5,113
	Alt 4	$93	$3	$0	$0	$0	$251	$20	$1	$106	$54	$34	$561
	Alt 5	$93	$3	$4,602	$0	$0	$221	$20	$1	$99	$50	$34	$5,124

ERDF = Environmental Restoration Disposal Facility.

Table D-2. Alternative 2 Cost Summary: Capital Costs, Periodic Costs, Non-Discounted Costs, and Present Worth Costs.

Site	Total Capital Cost	Non-Discounted Annual and Periodic Cost	Non-Discounted Cost	Total Present Worth Cost
Trenches 216-B-23 to –B-28 and 216-B-52	$20,000	$7,565,059	$7,585,059	$1,498,284
Cribs 216-B-14 to –B-19	$20,000	$7,424,289	$7,444,289	$1,470,123
Trenches 216-B-54 and B-58	$20,000	$6,841,212	$6,861,212	$1,337,480
Trenches 216-B-53A and -B-53B	$20,000	$6,841,212	$6,861,212	$1,337,480
Trench 216-B-29 to –B-34	$20,000	$7,404,289	$7,424,289	$1,450,123
Trench 216-B-20 to –B-22	$20,000	$7,001,982	$7,021,982	$1,385,640
Pipeline 200-E-114	$20,000	$4,399,674	$4,419,674	$930,158
Siphon Tank 200-E-14	$20,000	$4,419,674	$4,439,674	$950,158

Table D-3. Alternative 3 Cost Summary: Capital Costs, Periodic Costs, Non-Discounted Costs, and Present Worth Costs.

Site	Total Capital Cost	Non-Discounted Annual and Periodic Cost	Non-Discounted Cost	Total Present Worth Cost
Trenches 216-B-23 to –B-28 and 216-B-52	$339,400,757	$0	$339,400,757	$339,400,757
Cribs 216-B-14 to –B-19	$159,074,045	$0	$159,074,045	$159,074,045
Trenches 216-B-54 and –B-58	$2,041,542	$0	$2,041,542	$2,041,542
Trenches 216-B-53A and –B-53B	$1,073,219	$0	$1,073,219	$1,073,219
Trenches 216-B-29 to –B-34	$391,871,056	$0	$391,871,056	$391,871,056
Trenches 216-B-20 to –B-22	$155,321,414	$0	$155,321,414	$155,321,414
Pipeline 200-E-114	$557,214	$0	$557,214	$557,214
Siphon Tank 200-E-14	$5,113,232	$0	$5,113,232	$5,113,232

Table D-4. Alternative 4 Cost Summary: Capital Costs, Periodic Costs, Non-Discounted Costs, and Present Worth Costs.

Site	Total Capital Cost	Non-Discounted Annual and Periodic Cost	Non-Discounted Cost	Total Present Worth Cost
Trenches 216-B-23 to -B-28 and 216-B-52	$6,063,218	$41,782,152	$47,845,370	$14,825,736
Cribs 216-B-14 to -B-19	$2,408,149	$18,118,697	$20,526,846	$6,135,604
Trenches 216-B-54 and –B-58	$1,179,756	$9,233,557	$10,413,313	$3,022,536
Trenches 216-B-53A and –B-53B	$900,264	$6,596,331	$7,496,595	$2,181,719
Trenches 216-B-29 to –B-34	$5,508,699	$40,990,421	$46,499,120	$14,104,324
Trenches 216-B-20 to –B-22	$2,977,003	$20,727,586	$23,704,589	$7,264,624
Pipeline 200-E-114	$1,422,129	$6,874,510	$8,296,639	$2,874,791
Siphon Tank 200-E-14	$561,274	$2,521,663	$3,082,937	$1,087,446

Table D-5. Alternative 5 Cost Summary: Capital Costs, Periodic Costs, Non-Discounted Costs, and Present Worth Costs.

Site	Total Capital Cost	Non-Discounted Annual & Periodic Cost	Non-Discounted Cost	Total Present Worth Cost
Trenches 216-B-23 to –B-28 and 216-B-52	$14,019,218	$41,879,075	$55,898,293	$22,801,126
Cribs 216-B-14 to –B-19	$10,855,981	$18,201,774	$29,057,755	$14,600,056
Trenches 216-B-54 and –B-58	NA	NA	NA	NA
Trenches 216-B-53A and –B-53B	NA	NA	NA	NA
Trenches 216-B-29 to –B-34	$12,532,354	$41,314,379	$53,846,733	$21,385,481
Trenches 216-B-20 to –B-22	$5,784,353	$20,769,125	$26,553,478	$10,080,284
Pipeline 200-E-114	NA	NA	NA	NA
Siphon Tank 200-E-14	$5,123,690	$2,521,663	$7,645,353	$5,649,862

Table D-6a. Alternatives 2 and 3 Site Information.

Waste Site	Alternative 2					Alternative 3						
	Site Dimensions (ft)					Excavation Dimensions (ft)			Contaminated Volume (yd^3)	Excavated Volume (yd^3)	Overburden Soil Volume (yd^3)	Duration (days)
	Length	Width	Depth (bgs)	Pipe Depth (bgs)	Clean Overburden Depth	Length	Width	Depth				
Trenches 216-B-23 to –B-28 and 216-B-52	650	540	150	N/A	11	1,270	1,170	150	1,818,012	6,730,073	4,912,061	1,631
Cribs 216-B-14 to –B-19	385	225	220	N/A	11	1,225	1,065	220	697,674	8,430,000	7,732,325	936
Trench 216-B-58	210	20	25	N/A	10	285	95	25	2,020	14,480	12,460	53
Trench 216-B-54	210	20	25	N/A	10	285	95	25	2,020	14,480	12,460	53
Trenches 216-B-54 and –B-58												
Trenches 216-B-53A and –B-53B	220	20	25	N/A	11	295	95	25	2,280	15,330	13,050	34
Trenches 216-B-29 to –B-34	707.00	573	150	N/A	11	1,337	1,203	150	2,122,370	7,179,010	5,056,640	1,862
Trenches 216-B-20 to –B-22	610	240	150	N/A	10	1,220	850	150	770,010	5,235,018	4,465,007	785
Pipeline 200-E-114	1,200	3	11	10	9	1,200	36	11	307	997	660	30
Siphon Tank 200-E-14	27	12.75	16.5	N/A	7	52	37	17.5	169	651	482	25[a]

[a] Does not include duration of sludge removal.
N/A = not applicable.

Table D-6b. Alternatives 4 and 5 Site Information.

Waste Site	Alternative 4					Alternative 5						
	Capping Dimensions (ft)		Acres of Capping	Duration	Cap Type*	Excavation Dimensions (ft)			Contaminated Volume (yd^3)	Excavated Volume (yd^3)	Cap Type	Duration
	Length	Width				Length	Width	Depth				
Trenches 216-B-23 to -28 and 216-B-52	867	857	17	241	Modified RCRA C / Evapotranspiration	3,580 [a]	59	15	36,623	72,596	Evapo-transpiration	325
Cribs 216-B-14 to –B-19	602	442	6.1	104	Modified RCRA C / Evapotranspiration	264 [b]	44	20	31,008	31,008	Evapo-transpiration	213
Trench 216-B-58	See Trenches 216-B-54 and -58					Alternative 5 - Not Applicable						
Trench 216-B-54	See Trenches 216-B-54 and -58					Alternative 5 - Not Applicable						
Trenches 216-B-54 and –B-58	342	282	2.2	56	Modified RCRA C / Evapotranspiration	Alternative 5 - Not Applicable						
Trenches 216-B-53A and –B-53B	242	177	1	43	Modified RCRA C / Evapotranspiration	Alternative 5 - Not Applicable						
Trenches 216-B-29 to –B-34	924	790	16.7	243	Modified RCRA C / Evapotranspiration	3,000 [c]	59	15	30,690	60,834	Evapo-transpiration	279
Trenches 216-B-20 to –B-22	787	417	7.52	125	Modified RCRA C / Evapotranspiration	1,500 [d]	59	15	15,345	30,417	Evapo-transpiration	60
Pipeline 200-E-114	1,267	77	2.24	61	Modified RCRA C	Alternative 5 - Not Applicable						
Siphon Tank 200-E-14	104	90	0.2	32	Modified RCRA C	N/A	N/A	N/A	Tank was grouted in place	N/A	Evapo-transpiration	30 [e]

* Modified RCRA C = Modified RCRA Subtitle C Barrier (*Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq.).
[a] Total trench length includes - one trench at 580 ft and 6 trenches at 500 ft.
[b] The site is made up of six cribs each 44 ft by 44 ft.
[c] Total trench length includes - 6 trenches at 500 ft.
[d] Total trench length includes - 3 trenches at 500 ft each.
[e] Does not include duration of sludge removal.
N/A = not applicable.

APPENDIX E

RISK ASSESSMENT FOR AN INADVERTENT INTRUDER SCENARIO

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CONTENTS

FIGURES

TABLES

TERMS

EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ERDF performance assessment	BHI-00169
ILAW	immobilized low-activity waste
ILAW performance assessment	DOE/ORP-2000-24
RESRAD	RESidual RADioactivity (code)

APPENDIX E

RISK ASSESSMENT FOR INADVERTENT INTRUDER SCENARIO

E1.0 INTRODUCTION

Intruder scenarios are based on the framework documented in HAB Advice #132, "Exposure Scenarios Task Force on the 200 Area" (HAB 132). Inadvertent intruder scenarios are based on the possibility that an individual unwittingly (through human error or loss of knowledge concerning the location of contaminants) engages in an activity that results in contact with wastes left in place (10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste"). The reasonably anticipated future land use for the 200 Areas is continued industrial activities based, on DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, and the associated record of decision, 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)". For locations within the industrial area, the U.S. Department of Energy dose limits for the protection of workers and the affected public will be in effect for as long as facility management operations continue. After a period of 50 yr, it is assumed that all operations will have ceased, and public entry to the site will be restricted for an additional 100 yr by passive institutional controls, such as fences, signage, deed restriction, and covenants.

After the cessation of operations, protection of human receptors would be based on U.S. Environmental Protection Agency (EPA) guidance for protection of individuals receiving a reasonable maximum exposure. The goal is to achieve a 10^{-4} to 10^{-6} risk range, using a direct exposure dose of 15 mrem/yr above background as an operational guideline to achieve this goal.

For purposes of evaluating risk, it is presumed that after 150 years an intruder could obtain access to the area. Of the three intruder scenarios proposed for evaluation (see below), the third is considered to be the worst-case scenario, because exposure time would be the greatest. Therefore, the first and third scenarios will be used to provide bounding for the second scenario.

1. Future Construction Trench Worker Intruder Scenario
2. Future Well Driller Intruder Scenario (drill cuttings)
3. Future Rural Residential Intruder Scenario (drill cuttings).

In addition to the intruder scenarios and the baseline evaluations of industrial and groundwater protection scenarios (Appendix C), a hypothetical Native American scenario also is evaluated in the focused feasibility study. The hypothetical Native American scenario is intended to recognize the cultural and life-style differences of tribal activities under baseline conditions and is presented in Appendix C.

The Future Construction Trench Worker and Future Rural Residential Intruder Scenarios were evaluated for the following waste sites:

- 216-B-46 Crib
- 216-B-26 Trench
- 216-B-58 Trench.

E1.1 FUTURE CONSTRUCTION TRENCH WORKER INTRUDER SCENARIO

Contact with contaminants by inadvertently excavating a utilities trench or other construction activity (including the excavation of a basement or building foundation) through a waste site defines a reasonable maximum exposure event that could result in acute exposure to a future worker.

The exposed worker at a trench construction site is assumed to be exposed 10 h/day for 5 days. The dose to the worker is the sum of the contributions from inhaling resuspended dust and inadvertently ingesting soil, and from direct exposure at the center of an excavated trench with side shoring that exposes 12 m^2 of soil (2 m wide by 6 m long). It is assumed that a progressive advancement of the shoring is coupled with the excavation and backfill operation, thus limiting the horizontal extent of the exposed contamination. It also is assumed that the side shoring will provide shielding from radionuclides that are present. As such, the contaminated zone is modeled as a 12 m^2 by 2 m thick contamination zone (see Figure E-1 for a representation of the trench configuration).

E1.2 FUTURE WELL-DRILLER INTRUDER SCENARIO

This exposure scenario estimates risk and dose associated with inadvertently drilling a well at a waste site. The drill cuttings (i.e., uncontaminated and contaminated soil) are assumed to have been spread over the work area near the well. Based on the evaluations for DOE/ORP-2000-24, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* (ILAW performance assessment) and BHI-00169, *Environmental Restoration Disposal Facility Performance Assessment* (ERDF performance assessment), the diameter of the well for this evaluation is assumed to be 0.3 m (1 ft). Although consistent with the diameters used in Hanford Site performance assessments, this diameter is larger than the range of well diameters commonly found in local communities (10.2 to 25.4 cm [4 to 10 in.]). Use of this well diameter may overestimate the dose associated with this exposure scenario. The area on which the driller spreads the cuttings is assumed to be 200 m^2 (2,153 ft^2), a size historically used in Hanford Site performance assessments.

In the well driller intruder scenario, the soil mixing depth is assumed to be 15 cm (6 in.), a depth used in other on-site performance assessments. The worker at the well drilling site is assumed to be exposed 8 h/day for 5 days. The dose to the worker is the sum of the contributions from inhaling resuspended dust and inadvertently ingesting soil, and from direct exposure at the center of a 200 m^2 (2,153-ft^2) slab of contaminated soil for 40 h.

E1.3 FUTURE RURAL RESIDENTIAL INTRUDER SCENARIO

This scenario assumes that a receptor is residing within the area and has planted a garden using the drill cuttings taken from a well drilled through the waste site. The resident receives dose from direct exposure to the radiation field in the garden, inhales resuspended dust, ingests soil at the same rates as the well driller, and consumes garden produce grown in the contaminated soil. Consumption of groundwater is not included in this evaluation, because groundwater in this area currently is under remediation and is not available for use. This scenario is consistent with other inadvertent intruder evaluations conducted within the Central Plateau. The resident is assumed to spread the waste over a garden 200 m^2 (2,153 ft^2) in area and to a depth of 15 cm (6). The garden area was taken from the ILAW performance assessment (DOE/ORP-2000-24), because the size represents an area large enough to supply a significant portion of a person's vegetable and fruit diet, yet small enough to produce a higher (more conservative) estimation of dose (see Figure E-2 for a representation of the scenario).

The resident is assumed to spend 20 percent of the time in the garden, 60 percent of the time indoors exposed to dust from the garden, and 20 percent of the time off site. The predicted dose depends on the area of the resident's garden and the amount of time the resident spends in the garden. The radionuclide concentration in the soil, and consequently the dose rate, is inversely proportional to the size of the garden, which implies that a smaller garden will produce a larger dose. However, where direct doses dominate, a smaller garden area (i.e., 200 m^2 [2,153 ft^2]) produces only a moderate increase in total dose.

E2.0 CONCEPTUAL SITE MODEL

Initial concentration values used are presented in Tables E-1 through E-6 for the waste sites evaluated. Until exposure, formation of radionuclide daughter products, which also are present as initial products, are not added to initial concentration values. This results in a straight decay value for each radionuclide, using only the half-life of the radionuclides and the time of decay. The calculation for the construction worker assumes that the excavation has exposed the highest contamination concentration for each constituent. The calculations for the resident farmer assume that the cuttings are completely composed of the highest contamination concentration for each constituent. The contaminated volume is calculated from the surface to a depth of 75 ft below ground surface, with the rest of the cuttings being considered as noncontaminated soil. The lower depth limit for contamination was determined from examining the data from characterization wells in the area, which indicate contamination concentrations have dropped to less than 1 pCi/g. The exposure-point concentration for the rural residential intruder is based on dilution of the drill cuttings from being spread over the garden and mixed with soil as described previously.

E3.0 RISK ASSESSMENT METHODOLOGY

E3.1 EVALUATION OF POTENTIAL HUMAN HEALTH RISK

Human health risk resulting from radionuclide contaminants of potential concern was evaluated using the RESidual RADioactivity (RESRAD) computer model. The RESRAD code was developed by Argonne National Laboratory (*RESRAD for Windows* [ANL 2002]) to implement U.S. Department of Energy guidelines for allowable residual radioactive material in soil (DOE Order 5400.5, *Radiation Protection of the Public and the Environment*). The EPA evaluated the code for use in performing dose assessments to support the EPA guidance limit for radiation dose from contaminated sites to 15 mrem/yr above background (EPA 1997, OSWER No. 9200.4-18, *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*). The RESRAD determinations include calculating the total excess cancer risk for radionuclides using EPA 2001, *Health Effects Assessment Summary Tables* database, "Update of Radionuclide Carcinogenicity Slope Factors," "April 16, 2001 Update: Radionuclide Toxicity," available on the Internet at www.epa.gov/radiation/heast/index.html).

E3.2 RESRAD CALCULATION METHODOLOGY

RESRAD is a pathway analysis code that calculates radiation doses to a hypothetical individual interacting with a contaminated site. ANL/EAD-4, *User's Manual for RESRAD, Version 6*, provides information on the design and application of the RESRAD code. It describes the basic models and parameters used in the RESRAD code to calculate dose and risk from residual radioactive materials and the procedures for applying these models to calculate operational guidelines for remediation of soil contamination.

Exposure pathways were evaluated by RESRAD using a construction trench worker scenario. The construction trench worker scenario exposure pathway evaluations include exposure via inhalation, and inadvertent soil ingestion. The selected exposure pathways are consistent with the recommendations provided by ANL/EAD-4, except for the radon gas exposure pathway. Exposure to radon gas is not a pathway in the construction trench worker scenario because of a lack of enclosed areas that may capture significant amounts of radon. However, the occurrence of radon gas as a daughter product from decay of thorium and uranium isotopes is evaluated by RESRAD.

In addition, exposure pathways were evaluated by RESRAD using a rural residential intruder scenario, including annual irrigation of 0.76 m (30 in.) per year. The rural residential scenario exposure pathway evaluations include exposure via inhalation, inadvertent soil ingestion, external gamma radiation, and exposure from water-dependent pathways (e.g., ingestion of plants, meat, milk). The selected exposure pathways are consistent with the recommendations provided by ANL/EAD-4, except for the radon gas exposure pathway. Exposure to radon gas is not a pathway in the rural residential scenario because of a lack of enclosed areas that may capture significant amounts of radon. However, the occurrence of radon gas as a daughter product from decay of thorium and uranium isotopes is evaluated by RESRAD.

Although the RESRAD model provides default values, site-specific input parameters normally are used to obtain representative results. The site-specific and default input parameters used in this evaluation are consistent with those used in preparation of the baseline risk assessment presented in Appendix C of this focused feasibility study.

The 216-B-26 Trench original radionuclide concentration values measured were multiplied by 22 in an attempt to incorporate data gathered during radiological logging. The radiological logging indicated that gamma emissions were approximately 22 times greater than accounted for in sample analysis. Even though the logging was for gamma emissions, it was decided to multiply all of the radionuclide concentrations (even non-gamma emitters) by 22 to provide a conservative estimate of potential activity.

E3.3 DOSE AND RISK TO CONSTRUCTION TRENCH WORKER

Direct Exposure to Radionuclides

The parameters of the exposure pathways described in Appendix C were used with the RESRAD model to evaluate the dose and risk resulting from activities (i.e., concentrations) of individual radionuclides for the construction trench worker scenario. The RESRAD calculation was evaluated at various time intervals that equate with the dose and risk to the intruder. These timeframe intervals are applied to the original radionuclide concentration as the time of decay and generate radionuclide concentrations appropriate for the scenarios. The time increments are used to evaluate different timeframes of when institutional controls fail.

All of the waste sites present unacceptable incremental cancer risks at the start of the intruder scenario. With incremental time of radionuclide decay, all waste sites exhibit differing decreases in risk and dose (dependent on radionuclide concentration and decay rate). Radionuclide data used as input values were selected from the highest sampled concentration for each site, regardless of the depth where the concentration occurred. This provides the most conservative approach to the modeling.

Following is a summary for each representative site:

- 216-B-46 Crib Future Construction Worker Scenario

  Within 250 yr, the dose and risk have fallen below threshold values. See Figure E-3.

- 216-B-58 Trench Future Construction Worker Scenario

  Within 160 yr, the dose and risk have fallen below threshold values. See Figure E-4.

- 216-B-26 Trench Future Construction Worker Scenario

  Significant dose and increased risk are present until approximately year 450. The high initial dose is attributed to the Cs-137 present at the site. The long tailing effect is an attribute of the Pu-239/240, because its long half-life keeps the concentration elevated for thousands of years. Natural attenuation will result in potential doses being near the limit of 15 mrem/yr at 450 yr. See Figure E-5.

- 216-B-46 Crib Resident Farmer Scenario

  The resident farmer dose and risk values closely mirror the construction worker scenario. At the 250-yr mark, dose and risk fall below threshold levels. See Figure E-6.

- 216-B-58 Trench Resident Farmer Scenario

  At the 150-yr institutional control failure time, the resident farmer already has achieved acceptable dose and risk values. See Figure E-7.

- 216-B-26 Trench Resident Farmer Scenario

  Acceptable dose and risk values are reached at the 350-yr point. See Figure E-8.

E4.0 CONCLUSIONS

Considerable dose and risk reduction is achieved through the process of radionuclide decay. All sites achieve acceptable values within 500 yr, though this is longer than the assumed 150-yr mark for institutional controls.

E5.0 REFERENCES

10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," Title 10, *Code of Federal Regulations*, Part 61, as amended.

64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)," *Federal Register*, Vol. 64, No. 218, pp. 61615-61625, November 12, 1999.

ANL/EAD-4, 2001, *User's Manual for RESRAD, Version 6*, Argonne National Laboratory, Environmental Assessment Division, Argonne, Illinois.

ANL, 2002, *RESRAD for Windows*, Version 6.21, Argonne National Laboratory, Environmental Assessment Division, Argonne, Illinois.

BHI-00169, 1995, *Environmental Restoration Disposal Facility Performance Assessment*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, as amended, U.S. Department of Energy, Washington, D.C.

DOE/EIS-0222-F, 1999, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, U. S. Department of Energy, Washington, D.C.

DOE/ORP-2000-24, 2001, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version*, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

EPA, 1997, OSWER Directive 9200.4-18, *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 2001, *Health Effects Assessment Summary Tables* database, "Update of Radionuclide Carcinogenicity Slope Factors," "April 16, 2001 Update: Radionuclide Toxicity," U.S. Environmental Protection Agency, Washington, D.C., available on the Internet at http://www.epa.gov/radiation/heast/index.html.

HAB 132, 2002, "Exposure Scenarios Task Force on the 200 Area" (letter to K. Klein, H. Boston, J. Iani, and T. Fitzsimmons from T. Martin), Hanford Advisory Board Consensus Advice # 132, Richland, Washington, June 7.

Figure E-1. Conceptual Site Model for the Construction Trench Worker Scenario.

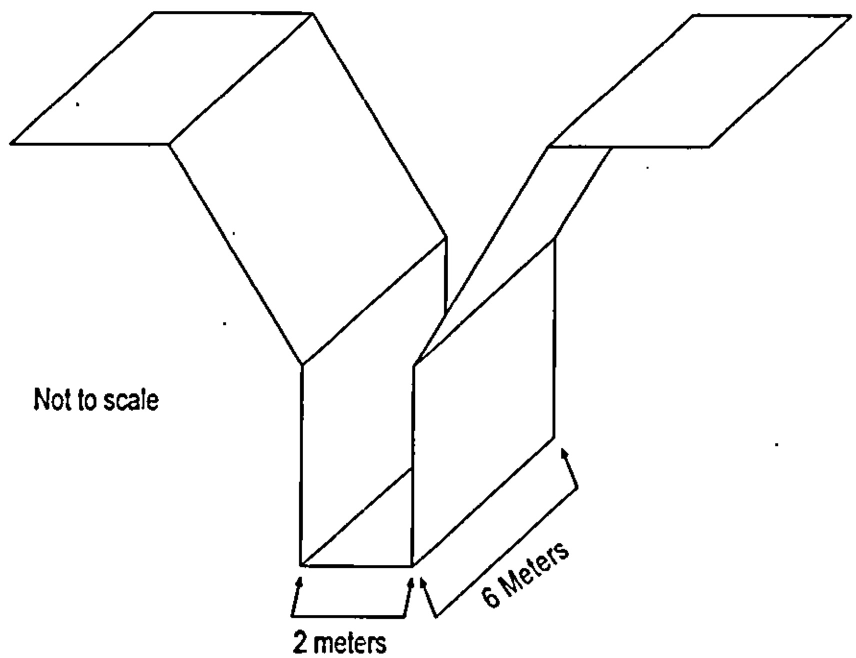

Figure E-2. Conceptual Site Model for the Rural Residential Intruder Scenario.

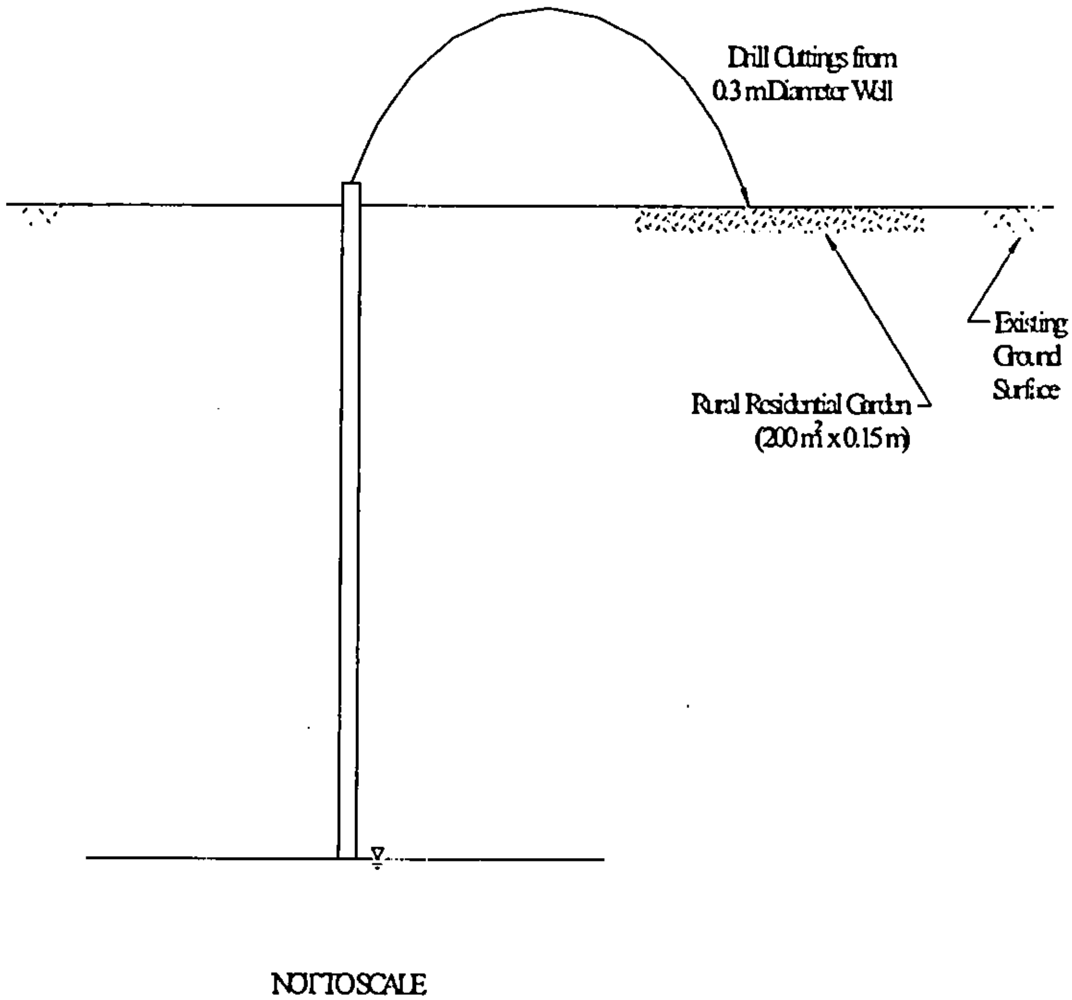

Figure E-3. 216-B-46 Crib Construction Trench Worker Scenario.

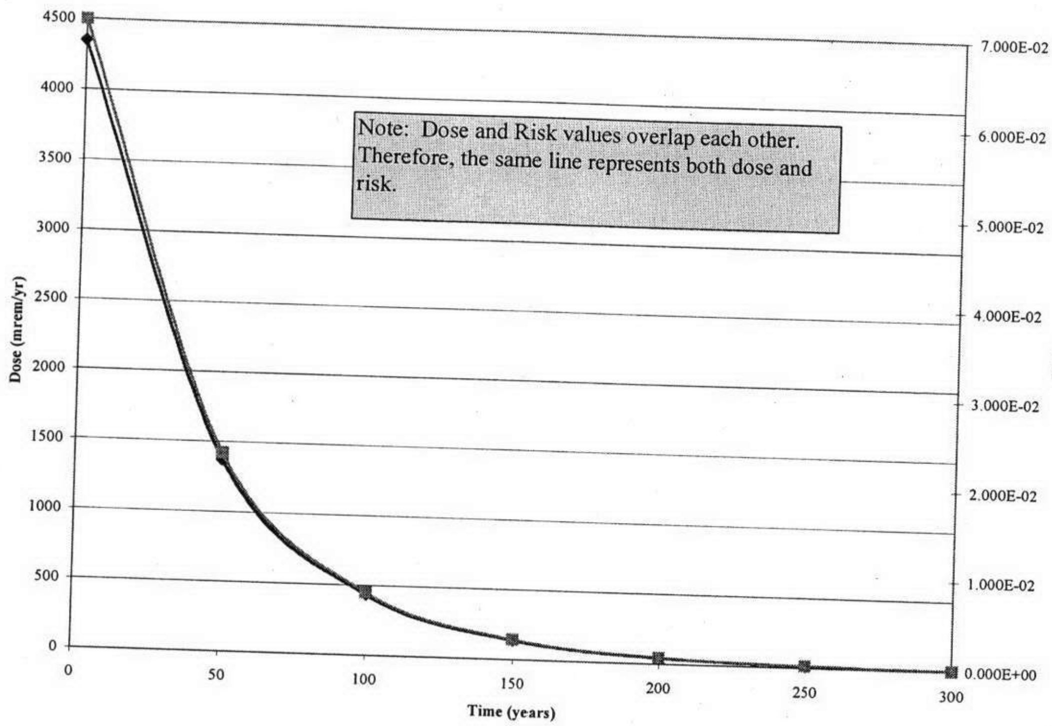

Figure E-4. 216-B-58 Trench Construction Trench Worker Scenario.

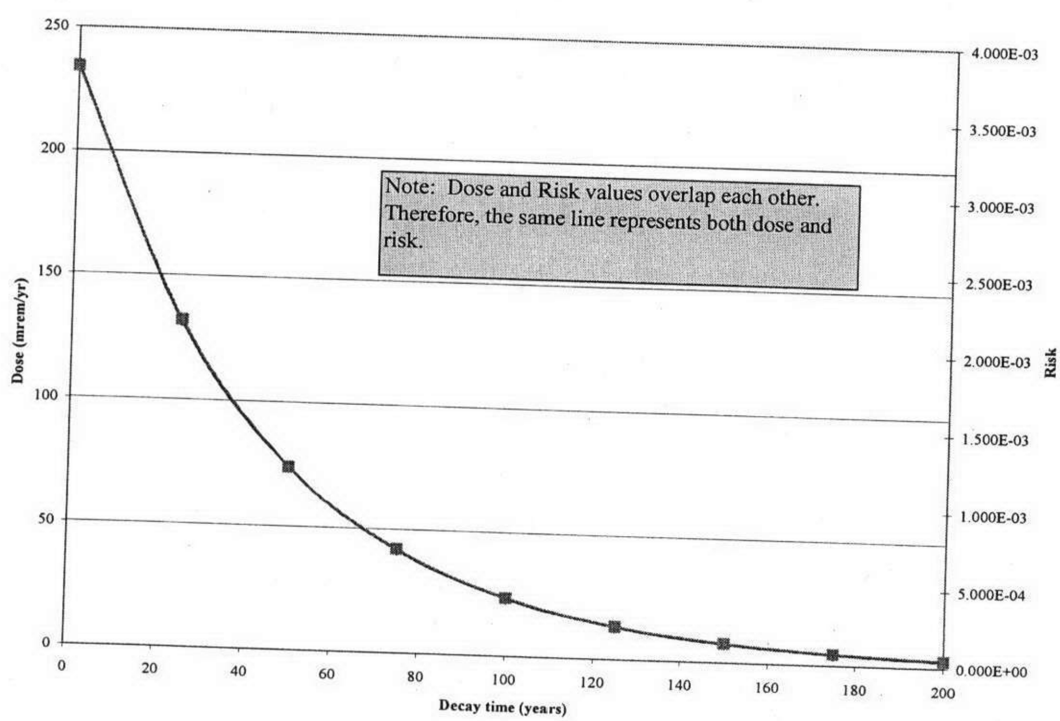

Figure E-5. 216-B-26 Trench Construction Trench Worker Scenario.

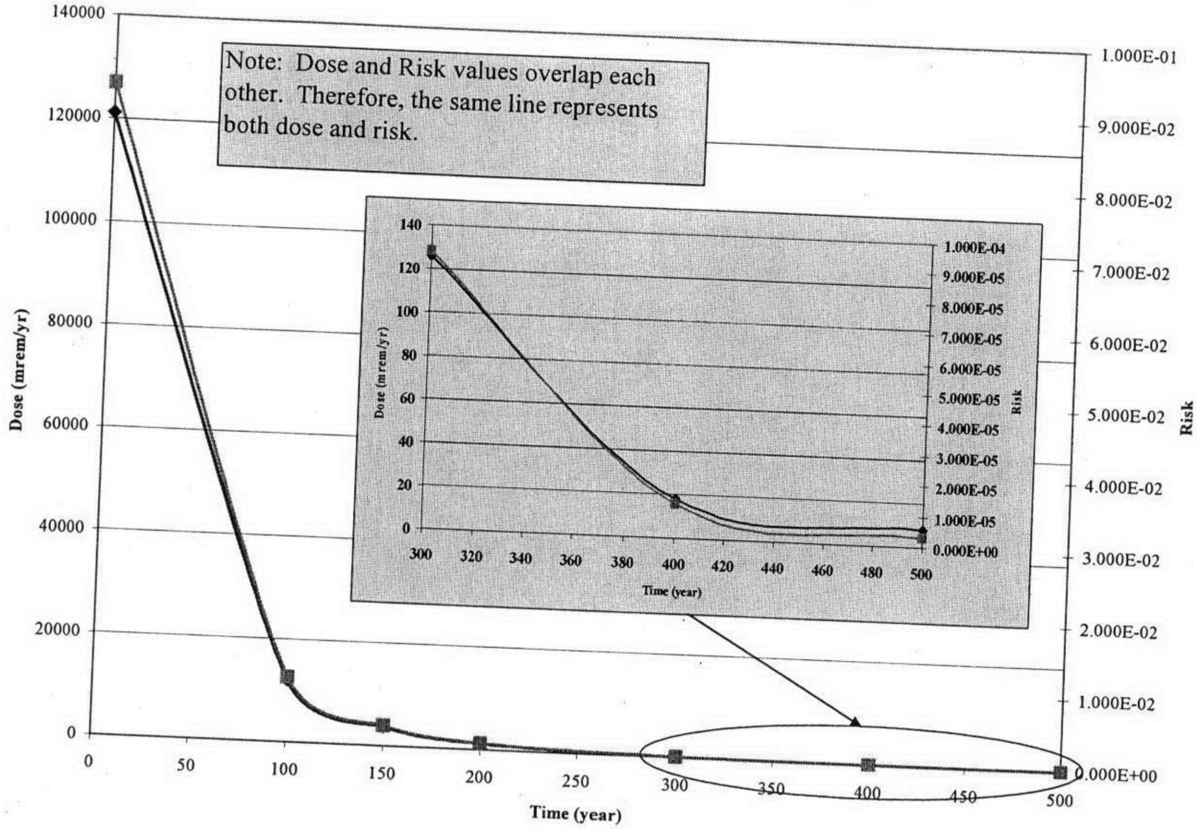

Figure E-6. 216-B-46 Crib Resident Farmer Scenario.

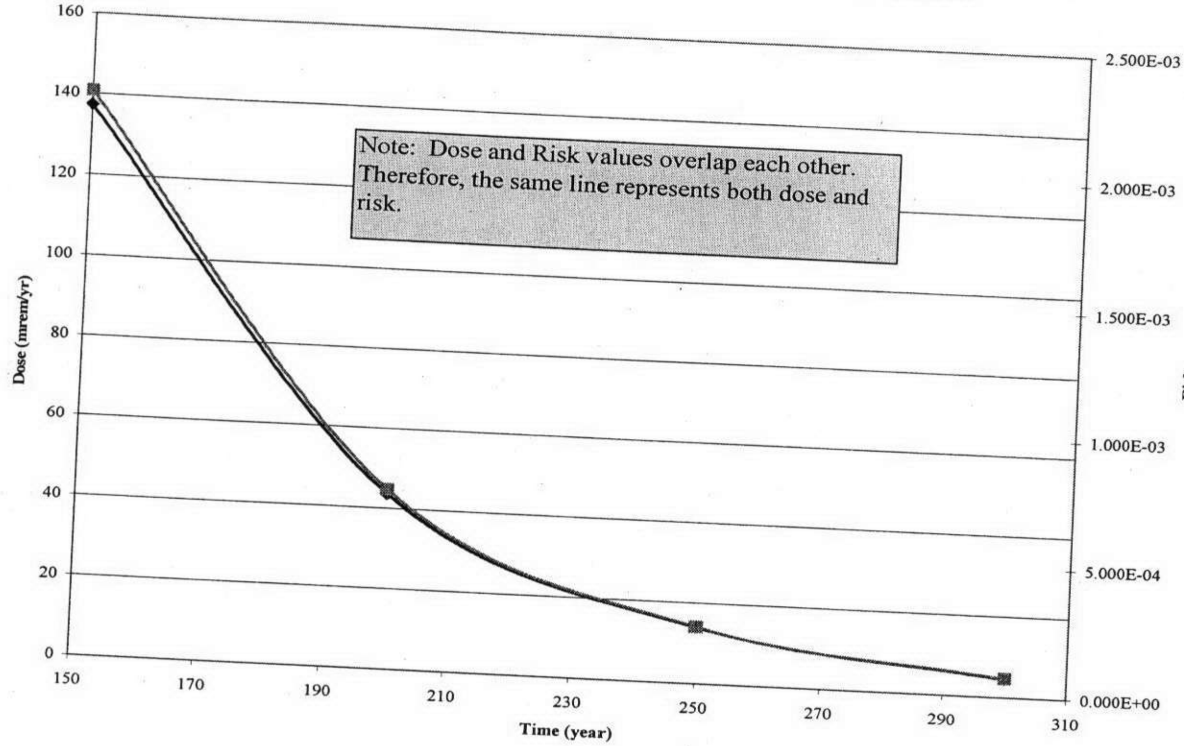

Figure E-7. 216-B-58 Trench Resident Farmer Scenario.

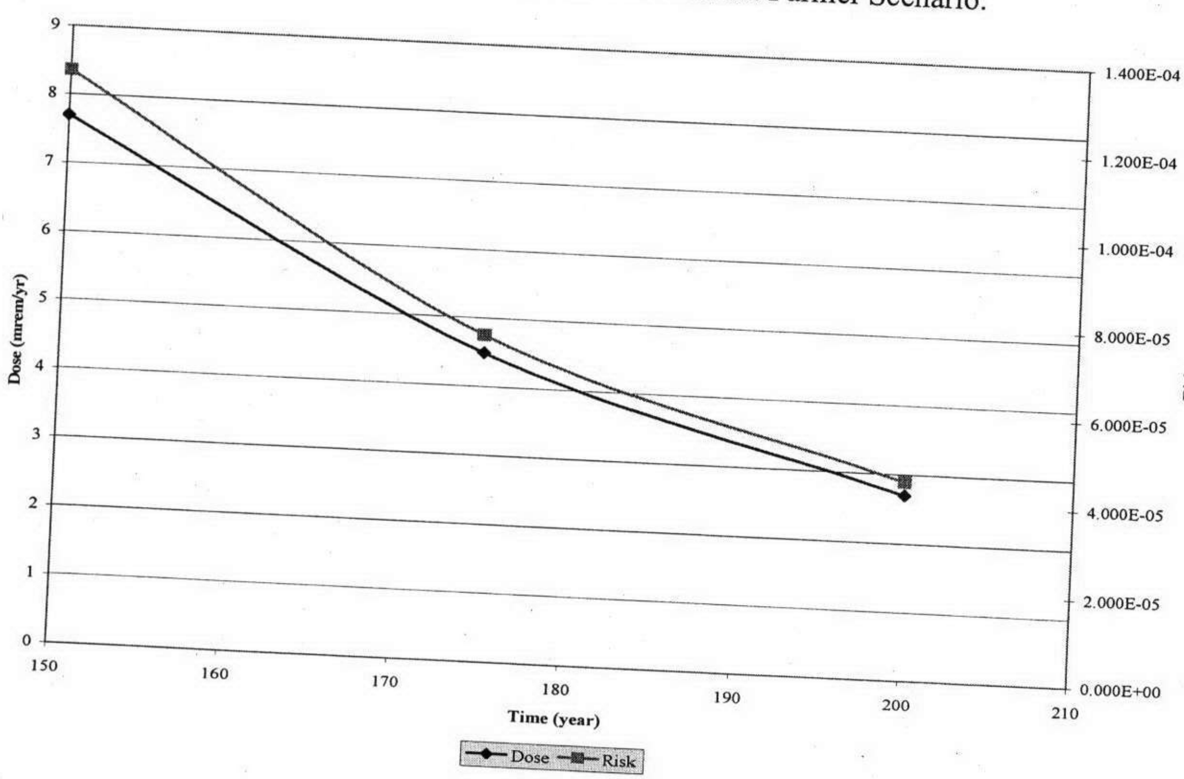

Figure E-8. 216-B-26 Trench Resident Farmer Scenario.

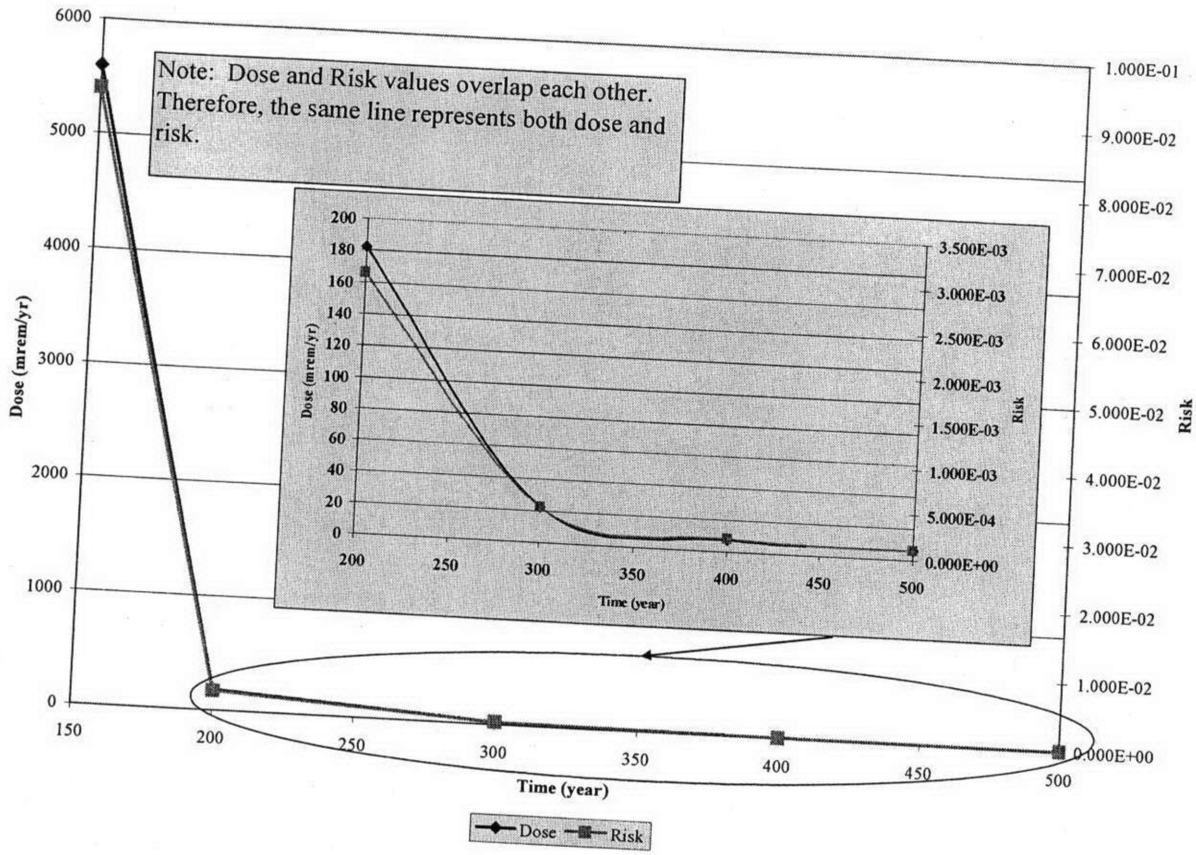

Table E-1. 216-B-26 Trench Construction Worker Scenario.

Constituent Name	Construction Trench Worker Initial RESRAD Values						
	216-B-26	216-B-26	216-B-26	216-B-26	216-B-26	216-B-26	216-B-26
	Years						
	0	100	150	200	300	400	500
Americium-241	4.620E+00	3.935E+00	3.632E+00	3.352E+00	2.856E+00	2.432E+00	2.072E+00
Cesium-134	8.800E-01	2.343E-15	1.209E-22	6.238E-30	1.661E-44	4.422E-59	1.177E-73
Cesium-137	1.164E+07	1.171E+06	3.716E+05	1.179E+05	1.186E+04	1.194E+03	1.202E+02
Cobalt-60	1.540E+00	3.022E-06	4.233E-09	5.930E-12	1.164E-17	2.283E-23	4.480E-29
Europium-154	-	-	-	-	-	-	-
Europium-155	2.200E+00	1.876E-06	1.733E-09	1.600E-12	1.364E-18	1.164E-24	9.923E-31
Plutonium-238	8.800E-01	3.996E-01	2.693E-01	1.815E-01	8.240E-02	3.742E-02	1.699E-02
Plutonium-239/240	4.290E+03	4.245E+03	4.223E+03	4.200E+03	4.156E+03	4.113E+03	4.070E+03
Plutonium-239*	-	-	-	-	-	-	-
Potassium-40	4.884E+02	4.884E+02	4.884E+02	4.884E+02	4.884E+02	4.884E+02	4.884E+02
Radium-226	1.980E+01	1.896E+01	1.855E+01	1.816E+01	1.739E+01	1.665E+01	1.594E+01
Radium-228	3.564E+01	2.073E-04	5.000E-07	1.206E-09	7.015E-15	4.081E-20	2.374E-25
Strontium-90	2.143E+07	1.802E+06	5.228E+05	1.516E+05	1.275E+04	1.073E+03	9.025E+01
Technetium-99	2.024E+03	2.023E+03	2.023E+03	2.023E+03	2.022E+03	2.021E+03	2.021E+03
Thorium-228	6.622E+01	1.239E-14	1.694E-22	2.317E-30	4.334E-46	8.108E-62	1.517E-77
Thorium-230	1.606E+01	1.605E+01	1.604E+01	1.603E+01	1.602E+01	1.601E+01	1.599E+01
Thorium-232	6.688E+01	6.688E+01	6.688E+01	6.688E+01	6.688E+01	6.688E+01	6.688E+01
Tritium	9.438E+02	3.413E+00	2.053E-01	1.235E-02	4.465E-05	1.615E-07	5.840E-10
Uranium-233/234	1.716E+02	1.715E+02	1.715E+02	1.715E+02	1.714E+02	1.713E+02	1.712E+02
Uranium-235	1.056E+01	1.056E+01	1.056E+01	1.056E+01	1.056E+01	1.056E+01	1.056E+01
Uranium-238	1.804E+02	1.804E+02	1.804E+02	1.804E+02	1.804E+02	1.804E+02	1.804E+02
Antimony-125	5.016E+01	6.805E-10	2.507E-15	9.233E-21	1.253E-31	1.700E-42	2.306E-53
Carbon-14	6.798E+01	6.716E+01	6.676E+01	6.636E+01	6.556E+01	6.477E+01	6.399E+01
Neptunium-237	4.400E-01	4.400E-01	4.400E-01	4.400E-01	4.400E-01	4.399E-01	4.399E-01
Nickel-63	4.642E+04	2.255E+04	1.572E+04	1.095E+04	5.321E+03	2.585E+03	1.256E+03
Tin-126	3.960E+00	3.957E+00	3.956E+00	3.955E+00	3.952E+00	3.949E+00	3.946E+00
Uranium-234	5.786E+01	5.784E+01	5.784E+01	5.783E+01	5.781E+01	5.779E+01	5.778E+01

Table E-2. 216-B-26 Trench Resident Farmer Scenario.

Constituent Name	Rural Resident Farmer Initial RESRAD Values						
	216-B-26	216-B-26	216-B-26	216-B-26	216-B-26	216-B-26	216-B-26
	Years						
	0	100	150	200	300	400	500
Americium-241	3.527E-02	3.005E-02	2.773E-02	2.559E-02	2.180E-02	1.857E-02	1.58E-02
Cesium-134	6.718E-03	1.789E-17	9.229E-25	4.762E-32	1.268E-46	3.376E-61	8.99E-76
Cesium-137	8.885E+04	8.942E+03	2.837E+03	9.000E+02	9.058E+01	9.116E+00	9.17E-01
Cobalt-60	1.176E-02	2.307E-08	3.232E-11	4.527E-14	8.883E-20	1.743E-25	3.42E-31
Europium-154	-	-	-	-	-	-	-
Europium-155	1.680E-02	1.432E-08	1.323E-11	1.222E-14	1.042E-20	8.884E-27	7.58E-33
Plutonium-238	6.718E-03	3.051E-03	2.056E-03	1.385E-03	6.291E-04	2.856E-04	1.30E-04
Plutonium-239/240	3.275E+01	3.241E+01	3.224E+01	3.207E+01	3.173E+01	3.140E+01	3.11E+01
Plutonium-239[c]	-	-	-	-	-	-	-
Potassium-40	3.729E+00	3.729E+00	3.729E+00	3.729E+00	3.729E+00	3.729E+00	3.73E+00
Radium-226	1.512E-01	1.448E-01	1.417E-01	1.386E-01	1.327E-01	1.271E-01	1.22E-01
Radium-228	2.721E-01	1.583E-06	3.817E-09	9.207E-12	5.356E-17	3.115E-22	1.81E-27
Strontium-90	1.636E+05	1.376E+04	3.991E+03	1.158E+03	9.737E+01	8.191E+00	6.89E-01
Technetium-99	1.545E+01	1.545E+01	1.544E+01	1.544E+01	1.544E+01	1.543E+01	1.54E+01
Thorium-228	5.056E-01	9.457E-17	1.293E-24	1.769E-32	3.309E-48	6.190E-64	1.16E-79
Thorium-230	1.226E-01	1.225E-01	1.225E-01	1.224E-01	1.223E-01	1.222E-01	1.22E-01
Thorium-232	5.106E-01	5.106E-01	5.106E-01	5.106E-01	5.106E-01	5.106E-01	5.11E-01
Tritium	7.205E+00	2.606E-02	1.567E-03	9.425E-05	3.409E-07	1.233E-09	4.46E-12
Uranium-233/234	1.310E+00	1.310E+00	1.309E+00	1.309E+00	1.308E+00	1.308E+00	1.31E+00
Uranium-235	8.062E-02	8.062E-02	8.062E-02	8.062E-02	8.062E-02	8.062E-02	8.06E-02
Uranium-238	1.377E+00	1.377E+00	1.377E+00	1.377E+00	1.377E+00	1.377E+00	1.38E+00
Antimony-125	3.829E-01	5.196E-12	1.914E-17	7.049E-23	9.563E-34	1.297E-44	1.76E-55
Carbon-14	5.190E-01	5.128E-01	5.097E-01	5.066E-01	5.005E-01	4.945E-01	4.89E-01
Neptunium-237	3.359E-03	3.359E-03	3.359E-03	3.359E-03	3.359E-03	3.359E-03	3.36E-03
Nickel-63	3.544E+02	1.722E+02	1.200E+02	8.363E+01	4.062E+01	1.973E+01	9.59E+00
Tin-126	3.023E-02	3.021E-02	3.020E-02	3.019E-02	3.017E-02	3.015E-02	3.01E-02
Uranium-234	4.417E-01	4.416E-01	4.415E-01	4.415E-01	4.414E-01	4.412E-01	4.41E-01

Table E-3. 216-B-46 Crib Construction Worker Scenario.

Constituent Name	Construction Trench Worker Initial RESRAD Values						
	216-B-46	216-B-46	216-B-46	216-B-46 Years	216-B-46	216-B-46	216-B-46
	0	50	100	150	200	250	300
Americium-241	-	-	-	-	-	-	-
Cesium-134	-	-	-	-	-	-	-
Cesium-137	2.76E+05	8.76E+04	2.78E+04	8.81E+03	2.80E+03	8.87E+02	2.81E+02
Cobalt-60	4.56E-01	6.39E-04	8.95E-07	1.25E-09	1.76E-12	2.46E-15	3.45E-18
Europium-154	-	-	-	-	-	-	-
Europium-155	-	-	-	-	-	-	-
Plutonium-238	6.31E+00	4.25E+00	2.87E+00	1.93E+00	1.30E+00	8.77E-01	5.91E-01
Plutonium-239/ 240	2.27E+02	2.26E+02	2.25E+02	2.23E+02	2.22E+02	2.21E+02	2.20E+02
Plutonium-239[c]	-	-	-	-	-	-	-
Potassium-40	1.47E+01	1.47E+01	1.47E+01	1.47E+01	1.47E+01	1.47E+01	1.47E+01
Radium-226	2.44E+00	2.39E+00	2.34E+00	2.29E+00	2.24E+00	2.19E+00	2.14E+00
Radium-228	-	-	-	-	-	-	-
Strontium-90	2.64E+05	7.66E+04	2.22E+04	6.44E+03	1.87E+03	5.42E+02	1.57E+02
Technetium-99	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02
Thorium-228	1.00E-02	1.37E-10	1.87E-18	2.56E-26	3.50E-34	4.79E-42	6.55E-50
Thorium-230	-	-	-	-	-	-	-
Thorium-232	-	-	-	-	-	-	-
Tritium	2.69E+01	1.62E+00	9.73E-02	5.85E-03	3.52E-04	2.12E-05	1.27E-06
Uranium-233/234	-	-	-	-	-	-	-
Uranium-235	-	-	-	-	-	-	-
Uranium-238	-	-	-	-	-	-	-

Table E-4. 216-B-46 Crib Resident Farmer Scenario.

Constituent Name	Rural Resident Farmer Initial RESRAD Values						
	216-B-46	216-B-46	216-B-46	216-B-46 Years	216-B-46	216-B-46	216-B-46
	0	50	100	150	200	250	300
Americium-241	-	-	-	-	-	-	-
Cesium-134	-	-	-	-	-	-	-
Cesium-137	2.26E+03	7.17E+02	2.27E+02	7.21E+01	2.29E+01	7.26E+00	2.30E+00
Cobalt-60	3.73E-03	5.23E-06	7.32E-09	1.03E-11	1.44E-14	2.01E-17	2.82E-20
Europium-154	-	-	-	-	-	-	-
Europium-155	-	-	-	-	-	-	-
Plutonium-238	5.16E-02	3.48E-02	2.35E-02	1.58E-02	1.06E-02	7.18E-03	4.84E-03
Plutonium-239/240	1.86E+00	1.85E+00	1.84E+00	1.83E+00	1.82E+00	1.81E+00	1.80E+00
Plutonium-239[c]	-	-	-	-	-	-	-
Potassium-40	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01	1.20E-01
Radium-226	2.00E-02	1.95E-02	1.91E-02	1.87E-02	1.83E-02	1.79E-02	1.75E-02
Radium-228	-	-	-	-	-	-	-
Strontium-90	2.16E+03	6.27E+02	1.82E+02	5.27E+01	1.53E+01	4.43E+00	1.29E+00
Technetium-99	9.82E-01	9.82E-01	9.82E-01	9.82E-01	9.81E-01	9.81E-01	9.81E-01
Thorium-228	8.18E-05	1.12E-12	1.53E-20	2.09E-28	2.86E-36	3.92E-44	5.36E-52
Thorium-230	-	-	-	-	-	-	-
Thorium-232	-	-	-	-	-	-	-
Tritium	2.20E-01	1.32E-02	7.96E-04	4.79E-05	2.88E-06	1.73E-07	1.04E-08
Uranium-233/234	-	-	-	-	-	-	-
Uranium-235	-	-	-	-	-	-	-
Uranium-238	-	-	-	-	-	-	-

Table E-5. 216-B-58 Trench Construction Worker Scenario.

Constituent Name	Construction Trench Worker Initial RESRAD Values						
	216-B-58	216-B-58	216-B-58	216-B-58	216-B-58	216-B-58	216-B-58
	Years						
	0	25	50	75	100	150	200
Americium-241	4.12E+02	3.96E+02	3.80E+02	3.65E+02	3.51E+02	3.24E+02	2.99E+02
Cesium-134	3.00E-02	6.81E-06	1.55E-09	3.52E-13	7.99E-17	4.12E-24	2.13E-31
Cesium-137	1.46E+04	8.22E+03	4.63E+03	2.61E+03	1.47E+03	4.66E+02	1.48E+02
Cobalt-60	9.96E+00	3.73E-01	1.40E-02	5.22E-04	1.95E-05	2.74E-08	3.83E-11
Europium-154	8.09E+00	1.13E+00	1.58E-01	2.20E-02	3.07E-03	5.98E-05	1.17E-06
Europium-155	6.00E-02	1.82E-03	5.54E-05	1.68E-06	5.12E-08	4.73E-11	4.36E-14
Plutonium-238	3.10E+01	2.54E+01	2.09E+01	1.71E+01	1.41E+01	9.49E+00	6.39E+00
Plutonium-239/ 240	3.10E+02	3.09E+02	3.08E+02	3.08E+02	3.07E+02	3.05E+02	3.04E+02
Plutonium-239*	-	-	-	-	-	-	-
Potassium-40	1.83E+01	1.83E+01	1.83E+01	1.83E+01	1.83E+01	1.83E+01	1.83E+01
Radium-226	6.00E-01	5.94E-01	5.87E-01	5.81E-01	5.75E-01	5.62E-01	5.50E-01
Radium-228	4.42E+00	2.17E-01	1.07E-02	5.24E-04	2.57E-05	6.20E-08	1.50E-10
Strontium-90	1.84E+04	9.91E+03	5.34E+03	2.87E+03	1.55E+03	4.49E+02	1.30E+02
Technetium-99	-	-	-	-	-	-	-
Thorium-228	6.89E+00	8.06E-04	9.42E-08	1.10E-11	1.29E-15	1.76E-23	2.41E-31
Thorium-230	1.05E+00	1.05E+00	1.05E+00	1.05E+00	1.05E+00	1.05E+00	1.05E+00
Thorium-232	4.42E+00	4.42E+00	4.42E+00	4.42E+00	4.42E+00	4.42E+00	4.42E+00
Tritium	8.94E+01	2.19E+01	5.38E+00	1.32E+00	3.23E-01	1.94E-02	1.17E-03
Uranium-233/234	5.80E-01	5.80E-01	5.80E-01	5.80E-01	5.80E-01	5.80E-01	5.79E-01
Uranium-235	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
Uranium-238	2.60E-01	2.60E-01	2.60E-01	2.60E-01	2.60E-01	2.60E-01	2.60E-01

Table E-6. 216-B-58 Trench Resident Farmer Scenario.

Constituent Name	Rural Resident Farmer Initial RESRAD Values						
	216-B-58	216-B-58	216-B-58	216-B-58	216-B-58	216-B-58	216-B-58
	Years						
	0	25	50	75	100	150	200
Americium-241	3.37E+00	3.24E+00	3.11E+00	2.99E+00	2.87E+00	2.65E+00	2.45E+00
Cesium-134	2.46E-04	5.58E-08	1.27E-11	2.88E-15	6.54E-19	3.37E-26	1.74E-33
Cesium-137	1.19E+02	6.73E+01	3.79E+01	2.14E+01	1.20E+01	3.82E+00	1.21E+00
Cobalt-60	8.15E-02	3.05E-03	1.14E-04	4.27E-06	1.60E-07	2.24E-10	3.14E-13
Europium-154	6.62E-02	9.24E-03	1.29E-03	1.80E-04	2.51E-05	4.89E-07	9.54E-09
Europium-155	4.91E-04	1.49E-05	4.53E-07	1.38E-08	4.19E-10	3.87E-13	3.57E-16
Plutonium-238	2.54E-01	2.08E-01	1.71E-01	1.40E-01	1.15E-01	7.76E-02	5.23E-02
Plutonium-239/ 240	2.54E+00	2.53E+00	2.52E+00	2.52E+00	2.51E+00	2.50E+00	2.48E+00
Plutonium-239[c]	-	-	-	-	-	-	-
Potassium-40	1.50E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01
Radium-226	4.91E-03	4.86E-03	4.81E-03	4.75E-03	4.70E-03	4.60E-03	4.50E-03
Radium-228	3.62E-02	1.78E-03	8.72E-05	4.28E-06	2.10E-07	5.08E-10	1.22E-12
Strontium-90	1.51E+02	8.11E+01	4.37E+01	2.35E+01	1.27E+01	3.67E+00	1.07E+00
Technetium-99	-	-	-	-	-	-	-
Thorium-228	5.64E-02	6.59E-06	7.71E-10	9.02E-14	1.05E-17	1.44E-25	1.97E-33
Thorium-230	8.59E-03	8.59E-03	8.59E-03	8.59E-03	8.59E-03	8.58E-03	8.58E-03
Thorium-232	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02
Tritium	7.32E-01	1.79E-01	4.40E-02	1.08E-02	2.65E-03	1.59E-04	9.57E-06
Uranium-233/234	4.75E-03	4.75E-03	4.75E-03	4.75E-03	4.74E-03	4.74E-03	4.74E-03
Uranium-235	1.64E-04	1.64E-04	1.64E-04	1.64E-04	1.64E-04	1.64E-04	1.64E-04
Uranium-238	2.13E-03	2.13E-03	2.13E-03	2.13E-03	2.13E-03	2.13E-03	2.13E-03

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